

**AVOIDING COLLAPSE: RESILIENCE AND SUSTAINABLE DEVELOPMENT IN
VULNERABLE SMALL ISLANDS**

By

Matthew Paul Bunce

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Avoiding Collapse: Resilience and Sustainable Development In Vulnerable Small Islands

PhD Thesis by Matthew Paul Bunce

Abstract

Small islands dependent on reef fisheries, farming and tourism are vulnerable to rising human and natural pressures and may target “sustainable” development. Marine Protected Areas (MPA) have a proven ability to meet ecological goals, such as restoring fisheries and preserving ecosystem function across scales. However, there is a comparative lack of scientific baseline data and social research which may help local MPA to overcome failures in achieving mixed conservation and development goals in populated coastal areas facing intense pressure. This fieldwork-based case study researched in French and Creole languages in the sub-tropical, mid-Oceanic island of Rodrigues (Mauritius, Indian Ocean) addresses two main questions: “Are conservation and development compatible goals for MPA in small islands reliant on fisheries and tourism?”, and, “Do social-ecological resilience concepts help clarify related issues of sustainability?”. Results from two quantitative surveys with fishers (n=93) and tourists (n=351) on one level support a “win-win” scenario for conservation and development. Local fishers’ knowledge suggested marine fish species including large predators of ecological and economic significance had been in decline for decades. Tourists’ stated willingness to pay to use Marine and Coastal Protected Areas could help fund conservation of biodiversity and fishery enhancement, with fee options ranging from MPA up to island-level. Beyond this, downside risks emerged from qualitative interviews with key informants (n=70) and historical analysis of island-level social-ecological resilience testing the explanatory value of the conceptual Adaptive Cycle model (Holling and Gunderson 2002). A recent crisis catalysed by severe drought (1970s) led to deep social and ecological changes (collapse in farming, migration and external dependence), while subsequent policies failed to address key drivers, instead creating negative feedbacks ensuring degradation extended outward from the coast. Remote and vulnerable small islands with few resources (forests, soil, water, energy) need significant capital inputs from higher scales which are seldom taken into account in determining the balance of winners and losers in conservation and development policy at MPA or island level. A lack of inter-island trust (social capital), water scarcity, climate change and migration arise as critical issues for the future. Rodrigues characterises the secondary importance of island regions within larger island states, and underlines the cross-scale and cross-temporal nature of sustainability in resilience terms. This thesis’ main contribution lies in its first demonstration of shifting baselines in an island reef fishery or MPA context. Findings contributed to the establishment of MPA in the fieldwork site of Rodrigues, and are of broad relevance for MPA policy across the tropics and beyond. More studies are needed across other ecosystems and cultures.

Contents

	Abstract	1
	Contents	2
	List of Figures	8
	List of Tables	10
	Abbreviations	12
	Acknowledgements	13
	Author's Declaration	15
1	Chapter 1 Introduction	16
1	Background	16
2	Thesis aims and objectives	17
3	Chapter objectives and research approach	18
4	Structure	18
5	Chapter development (summaries and abstracts)	19
2	Chapter 2 Literature Review	30
1	Introduction	30
2	Global environmental degradation and Marine Protected Areas	30
2.1	Marine Protected Areas	31
2.2	"Win-win" conservation and development	33
3	Resilience	35
4	Selection of research questions guiding aims and objectives	40
4.1	Small islands	40
4.2	Small island reef tourism	42
4.3	MPA science gaps and local knowledge	43
4.4	Financing conservation	44
4.5	Institutions	46
5	Summary	48
3	Chapter 3 Managing Collapse: Resilience and Sustainable Development in Vulnerable Small Islands	50
1	Abstract	50
2	Introduction	50
2.1	Resilience	51
2.2	Aims and objectives	52
2.3	Research site	53
3	Methodology	54
3.1	Terms	54
3.2	Research Approach	55
3.3	Data collection	56
4	Historical context	58
5	Results	65
5.1	Relating the conceptual Adaptive Cycle to historical social-ecological change	65

5.2	Conditions leading to collapse	67
1.	Change in five capitals	67
2.	Summary	70
5.3	Elite perceptions of social-ecological change	70
5.4	Reorganisation after collapse	75
1.	Migration	75
2.	Fishing incentive	76
3.	Collapse of farming, rise of state sector	77
4.	Land tenure and water management	78
5.	Reforestation	79
6.	Donor projects	80
7.	Inter-island power shift – rise of strong leader	80
8.	Dependence	81
9.	Tourism	81
5.5	Proposed shift in island “state” or “configuration” (MIRAB)	82
5.6	Summary and key issues	85
1.	Missed opportunities	86
2.	Scale and capital flows	86
3.	Trust	87
4.	Inter-island relations	87
5.	External stressors	88
6.	Back to the future?	89
5.7	Results limitations	89
6	Discussion	90
7	Conclusions	97
4	Chapter 4 Shifting Baselines in Fishers’ Perceptions of Island Reef Fishery Degradation	98
1	Abstract	99
2	Introduction	100
2.1	Aims and objectives	101
2.2	Research site and MPA	102
3	Methodology	103
3.1	Surveys and interviews	103
3.2	Data collection	105
3.3	Sampling	106
3.4	Data analysis	107
4	Results	107
4.1	Social context	107
4.2	Fisher profile	108
4.3	Fishers’ perceptions of fish and fishing ground depletion	110
4.4	Fishers’ perceptions of decline in indicator species	115
4.5	Fishers’ indications of decline in top predators (sharks)	117
4.6	Island level environmental decline	119

4.7	Study limitations	120
5	Discussion	122
5.1	1. Evidence of shifting baselines	122
	2. Island-level significance	122
	3. Shifting baselines in data-poor MPA development contexts	123
5.2	Policy implications	124
	1. Integrated response	124
	2. Risks of multiple objectives	125
	3. Building social-ecological resilience	125
	4. Recovery trajectories	126
5.3	Future studies	126
6	Conclusions	127

5	Chapter 5 Tourist User Fees for Small Island Marine Protected Areas	129
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1	Abstract	130
2	Introduction	130
2.1	Coral reef resilience	130
2.2	MPA and coral reef tourism	131
2.3	Tourism risks to small islands	131
2.4	Financial constraints	132
2.5	MPA tourism fees for funding conservation	132
2.6	Aims and objectives	133
	1. Regional gap in MPA funding in small islands	133
2.7	Research site	134
	1. Fishery pressure	134
	2. Small island tourism	135
	3. Biodiversity and nature tourism	135
	4. Marine and (coastal) protected areas (MCPA)	136
3	Research methodology	138
3.1	Survey	139
3.2	Sampling	140
3.3	Data analysis	141
4	Results	141
4.1	Tourist profile	141
	1. Socioeconomic	141
	2. Visit patterns	142
	3. Visit motivation	143
	4. Perceptions of environment	143
	5. Lagoon activity	144
4.2	Willingness to pay (WTP) to use Marine and Coastal Protected Areas	144
	1. Residency	146
	2. Income	147
	3. Endemics	148
	4. Trip satisfaction	148

5.	Environmental state	149
6.	Other	149
4.3	Stakeholders' qualitative perceptions (MCPA, fees and tourism development)	150
1.	Tourists' conceptions of Rodrigues Island	150
2.	Tourists' perceptions of fee regimes	152
3.	Tourism operators perceptions of MPA	153
4.	Fishers' qualified support for MPA	143
5.	Conservation and development conflict	155
4.4	Study limitations	155
5	Discussion	156
5.1	Policy implications	159
1.	Limitations to WTP	161
6	Conclusions	162
6	Chapter 6: Structural Constraints to Transformation in Small Islands	164
1	Abstract	165
2	Introduction	165
2.1	Aims and objectives	167
3	Methods	167
4	Results	168
4.1	Marine and Coastal Protected Area (MCPA) project background and co-management	168
1.	Twin island development	168
2.	Decentralisation and environmental management	169
3.	MCPA in Rodrigues	169
4.	MCPA Co-management	170
5.	ICZM	172
6.	Donor linkages	173
7.	Summary	174
4.2	Fishers' perceptions	175
1.	Causes of degradation and solutions	176
4.3	Alternative income sectors	177
1.	Livelihood pressure	178
2.	Fisheries (enforcement)	178
3.	Tourism (uncertainty, style, benefit capture)	181
4.	Agriculture	185
5.	Water criticality	187
4.4	Institutions and culture	188
1.	Power	188
1.	Coordination	189
2.	Island-level approach	190
3.	Priorities	191
4.	Capacity	191
5.	Socio-cultural constraints (governance style)	192

4.5	Summary – key institutional constraints	194
5	Discussion	195
5.1	Key points	195
	1. Information gaps	197
	2. Level of decisions	197
	3. Small island institutions	198
	4. ICZM	199
	5. Co-management and property rights	200
	6. Strengthening capitals	200
5.2	Case study lessons	201
	1. Instability and “hot groups”	201
	2. Livelihoods and enforcement	202
	3. Reconciling “win-win” in priorities	202
	4. Fishers, farmers and tenure	203
	5. Trade-offs	204
	6. Climate change and development	204
5.3	Further studies	205
6	Conclusions	206
7	Chapter 7 Summary: DPSIR indicators for MPA in Small Islands	208
1	Abstract	209
2	Introduction	209
3	Conceptual framework (DPSIR)	210
	1. DPSIR and integrated island MPA	212
3.2	DPSIR categorisation	213
	1. Proposed modification to DPSIR model	214
4	Results	216
4.1	Case study summary: using modified DPSIR for sustainable development	216
4.2	Key research findings related to DPSIR	217
	1. Drivers	218
	2. Pressures	218
	3. State (change)	219
	4. Impact	220
	5. Response (policy or otherwise)	220
	6. Migration	221
4.3	Proposed policy indicators for discussion	223
4.4	Study limitations	223
5	Discussion	225
6	Conclusions	226
8	Chapter 8: Conclusions	227
8.1	Summary	227
8.2	Conclusions	228
	1. Key points	

2.	Implications for small islands	231
8.3	Research limitations	233
8.4	Contribution to knowledge	233
8.5	Beneficiaries	234
8.6	Future study	235
9	Appendices	236
1	Sample interview transcripts (Chapter 5) abridged to highlight key issues – see also appendix 3	
2	a) Sample fishers' survey questionnaire (Chapter 4) questionnaire for eliciting perceptions of issues raised in all chapters but specifically shifting baselines	239
	b) Tourist survey questionnaire used to elicit expressions of willingness-to-pay, with sample spreadsheet of tourists accompanying qualitative comments	242
3	CD questionnaire copies (attached)	
4	Illustrative linkage between economic evaluation of the environment (Ch. 5) and Driver-State-Pressure-Impact-Response framework (Ch. 7)	247
5	Representative elite perceptions of key issues relating to the social-ecological resilience of Rodrigues island, and showing significant obstacles to resource management and prospects for effective MPA management	248
6	a) Potential vulnerabilities and impacts from climate change in Rodrigues, and	250
	b) Cross-scale trends: vulnerability and global change	
7	Distribution (%) of diving tourists' WTP-Marine Park (n=167)	251
8	Distribution (%) of tourists' WTP-Marine and Coastal Protected Area (n=351)	251
9	Contextual islander perceptions relevant to achieving conservation and development goals linked to Rodrigues' plan for a co-managed MCPA	252
10	Island predicament: excerpted quotes from a recorded interview (2006) with Rodrigues' Regional Assembly leader (JR) shortly before his accession to power	252
10	References	255
	(Peer-reviewed publications, submissions by thesis completion date: 19 pages)	270

List of Figures

Chapter 1

- Figure 1** Conceptual linkage of chapters as issues arising and feeding back into policy analyses. Resilience (Chapter 3) concepts based on the figure-of-eight Adaptive Cycle (Gunderson and Holling 2002) help discover long-term issues and drivers of social-ecological resilience. The Drivers-Pressures-State-Impact-Response (Chapter 7) framework of issue classification helps to manage this on a faster policy cycle related to social and ecological state 29

Chapter 2

- Figure 2** Graph of worldwide expansion of MPA to 2005 by cumulative area covered (hectares) and % split by type of protection given (UNEP/WCMC 2005) 32
- Figure 3** The Adaptive Cycle (Holling and Gunderson 2002), showing relationship between accumulation (r) and conservation of capital (K), its release (Ω) and re-organisation (α). Potential for resilience is reduced by exploitation (or accumulation) of capital and during release (or collapse phase Ω). Resilience may be rebuilt during phases of conservation and reorganisation. Whether social and ecological resilience are related is uncertain (Adger 2000). Components of resilience may have cycles at slower or faster rates, and/or at different scales. 36

Chapter 3

- Figure 4** Map showing location of four marine reserves gazetted in northern Rodrigues in 2007 and a preliminary boundary for a UNDP/GEF funded Marine Protected Area in the south (The main lagoon reef flat is denoted by the light grey area in the map marked 'reefs') – *n.b. map repeated in chapters* 52
- Figure 5** The Adaptive Cycle (Holling and Gunderson 2002), as in Fig. 3. Connectedness on a social level may refer to integration of credit and trading systems, on a natural level the patchiness of coral reefs, an attribute of resilience that may decrease with exploitation (r), be restored through conservation and degenerate if this fails. 56
- Figure 6** Timeline with problematic identification of distinct (but here suggested) phases of collapse (red) or recovery (green) in social-ecological systems (re Adaptive Cycle of Gunderson and Holling 2002) due to data gaps or any signs that social/ecological occur in phase. 66
- Figure 7** (a) Rodrigues' annual rainfall (Pte Canon) as a 5-yr moving average (left) showing the severity of a long 1970s drought with hard cyclones at each end (*Data: Mauritius Meteorological Office*) and (b) Three generations of fishers' ($n=93$: of which 18-29 years old, $N=30$, 30-49 years old $N=38$ and 50-80 years old, $N=25$) were questioned about period(s) of ecological change: "Has there been a time which radically changed Rodriguan's ability to fish and farm in balance with nature?" and "If so, when?". Year of cited change (x-axis) and % age group citing year (grouped into half decades) show on y-axis. Boxes below x-axis show breakdown of number of respondents by age group (%). 71
- Figure 8** Population growth by decade (1851-2000), with a post-war stabilisation (decade 10) (dotted line) compared to the trend (solid). This was followed by renewed exponential growth in population from 1951 to 1981 (decades 11-13). Population thereafter stabilised compared to the trend following a 75

long and severe 1970s drought. Rising emigration at rates above natural increase was enabled by transport links and economic opportunity in Mauritius and, for those with the means, Europe and Australia.

Chapter 4

- | | | |
|------------------|---|-----|
| Figure 9 | Number of species cited as depleted by three generations of fishers (<i>Kruskal-Wallis test Chi-squared = 21.4 p= <0.001. Boxes show median, 5, 25, 50 and 95th percentiles of the data</i>) | 111 |
| Figure 10 | Range and mean estimated weights of largest white-blotched grouper landed by three generations of fishers recalling their best ever day's catch (<i>one-way ANOVA, p=<0.001, LSD, groups significantly different p=<0.05</i>) | 116 |
| Figure 11 | Range and mean of highest number of grouper caught by three generations of fishers recalling their best fishing day (<i>One way ANOVA, p=<0.001, LSD significant difference between Old and Young age groups, p=<0.05</i>) | 116 |

Chapter 5

- | | | |
|------------------|---|-----|
| Figure 12 | Correlation of divers' (n=167) WTP-MPA and WTP-McPA (Spearman's rho test=0.684, p=<0.001). Bars show range, dots show mean (95% CI). | 145 |
| Figure 13 | Correlation between WTP-MPA and residency, showing lowest WTP among residents of France and Reunion. Bars show range, dots show mean (95% CI) | |
| Figure 14 | Relationship between WTP-McPA and income (when including low WTP among non-declarers of income. Bars show range, dots mean (95% CI) | 148 |
| Figure 15 | Relationship between WTP-McPA and visit duration, showing reduced WTP potential for longer visits. Bars show range, dots mean (95% CI) | 149 |

Chapter 6

- | | | |
|------------------|--|-----|
| Figure 16 | Illustrative cycle of environmental degradation through failures to address institutional aspects of marine resource use: problems identified in Rodrigues related to common ICZM fisheries policy problems | 173 |
| Figure 17 | Cross-scale hierarchy of institutional linkages likely to influence plans for co-management of Rodrigues' Marine and Coastal Protected Area/reserves | 174 |
| Figure 18 | Main causes of fishery decline, solutions suggested by >10% of 93 fishers | 176 |
| Figure 19 | Left: Fishing loans (Mauritian rupee) showing upward trend (middle) led by sharp rise in off-lagoon sector (top, n=23, with 283% rise 2002-05) vs. lagoon (bottom, n=277, 26% rise). Right: Annual fishing boat registrations outstripping rise in registered fishers suggesting rising effort, with rising range and intensity as boats access lagoon /off-lagoon areas | 180 |
| Figure 20 | Annual % change in tourist arrivals in Rodrigues island | 182 |

Chapter 7

- | | | |
|------------------|---|-----|
| Figure 21 | Modified DPSIR framework adapted to small islands dependent on natural resources - fisheries, farming and tourism. The 1-5 step cycle is adapted to include external variability in social/economic terms (XS), in addition to XN (natural science). Islands have only marginal /no control in both cases. However, a loose linkage is also created here between XS, policy responses and XN, reflecting island roles in sustaining unsustainable practices (e.g. marketing unsustainable tourism, open access ocean fishing) with cumulative impacts in large areas of global EEZ. Policy-makers may seek to influence XS. | 215 |
|------------------|---|-----|

List of Tables

Chapter 3

Table 1	Elite perceptions suggesting a severe 1970s drought acted as catalyser of social-ecological change in Rodrigues Island and, it is proposed, a "collapse" in terms of Holling's adaptive cycle of change in capitals	73
Table 2	Slow and fast variables proposed as contributory to a shift in Rodrigues' social-ecological configuration to a regional MIRAB-style economy	84
Table 3	Proposed slow-changing variables driving island-level change, and their possible interactions with faster variables to produce undesirable impacts	84

Chapter 4

Table 4	Fishers' perceptions of fishery decline or depletion and outward expansion of effort from lagoon fishery to areas beyond the fringing reef edge	110
Table 5	Largest 25 species (cms) cited as depleted by three generations of fishers' showing cross-generational variation in frequency of mention (% age group)	113
Table 6	Species most cited as depleted by three generations of fishers, ranked by frequency of mention (%) and showing cross-generational difference (age group)	114
Table 7	Older fishers' interview comments on depletion of a grouper (<i>Epinephelus multinotatus</i> , Creole: Vieille Plate) potentially indicative of marine reserve success and of relevance to fee-paying tourists (divers)	115
Table 8	Older fishers' perceptions in interviews of shark species reduction in Rodrigues' main lagoon fishery	118
Table 9	Perceptions of fishery decline and environmental change (% of age group) among three generations of fishers (Young, Medium, Old)	119
Table 10	Selected fishers' memories in interviews of fishery decline in Rodrigues Island	120

Chapter 5

Table 11	Variation in tourist motives for visiting Rodrigues (ranked high =1 to 5 = low) by country of residence (bracketed columns show standard deviation)	143
Table 12	Socioeconomic factors correlating more strongly with WTP than tourists' visit motives or perceptions of environmental state (for McPA and/or MPA)	145
Table 13	Diving participation rates showing high fee potential from countries 'Other' than those currently dominating diving tourism (French-speaking countries)	147
Table 14	Generalised statements of tourists' reasons for and against WTP to enter Marine and Coastal Protected Areas and/or Marine Protected Areas	153
Table 15	Fishers' (n=93) perceptions of benefits of MPA-related tourism (%)	154

Chapter 6

Table 16	Tourism strategic projections for Rodrigues, with overall island water demand	181
Table 17	Institutional constraints to natural resource management at regional island level in Rodrigues, within Republic of Mauritius (Adapted from Tompkins and Adger 2002)	194

Chapter 7

Table 18	Proposed social-economic-ecological indicators for assessing impacts of conservation and development policy with reference to MPA in Rodrigues island	224
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Abbreviations

AIDS	Acquired Immune Deficiency Syndrome
BWA	Bad Weather Allowance (for fishing)
CBD	Convention on Biodiversity
CI	Confidence Interval (statistical)
CITES	International Convention on Trade in Endangered Species
CS	Constant Stock
CSO	Central Statistics Organisation (Mauritius)
CVM	Contingent Valuation Methods
DCP	Decentralised Co-operation Project
DOM	Overseas Department (administrative unit of France)
DPSIR	Drivers-Pressures-State-Impact-Response
EIA	Environmental Impact Assessment
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Act
EU	European Union
FAD	Fish Aggregating Device
FAO	Food and Agriculture Organisation
FPS	Fisheries Protection Service
FRTU	Fisheries Research and Training Unit
GEF	Global Environment Facility
GOM	Government of Mauritius
ICM	Integrated Coastal Management
ICZM	Integrated Coastal Zone Management
IFAD	International Fund for Agricultural Development
IMPAMB	Integrated Marine Protected Area Management Board
IOC	Indian Ocean Commission
IPAT	Impact=Population-Behaviour-Lifestyle-Affluence-Consumption
IUCN	World Conservation Union
MCPA	Marine and Coastal Protected Area
MDG	Millennium Development Goals
MIRAB	Migration-Remittances-Aid-Bureaucracy
MLC	Mauritius' Legislative Council
MPA	Marine Protected Area
MSY	Maximum Sustainable Yield
NCG	National Coast Guard
NGO	Non-Governmental Organisation
NTZ	No-Take Zone (in MPA)
PMU	Project Management Unit
RRA	Rodrigues Regional Assembly
SADEC	Southern African Development Community
SD	Standard Deviation
SIDPR	Sustainable Island Development Project for Rodrigues
SIDS	Small Island Developing States
SITE	Small Island Tourist Economy
SWIO	South-Western Indian Ocean
TOM	Overseas Territory (of France)
UN	United Nations
UNCLOS	UN Convention on the Law of the Sea
UNDP	United Nations Development Programme
WIO	Western Indian Ocean
WTO	World Tourism Organisation
WTO	World Trade Organisation
WTP	Willingness-to-Pay
WTP-MPA	Willingness-to-Pay to use an MPA (tourists)

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Dedication

For patience, and happiness together in the Indian Ocean, this thesis belongs to my daughters, Ava and Marli, and their ever-loving mother Bettina. Giving up her work, and much else, Bettina's start-up business Beaucoco provides fair trade livelihoods for Rodrigues' disabled.

Good-bye Bernard Bunce – who shared his love of the sea

Author's Declaration

This interdisciplinary study was fully funded in an open scholarship competition run nationally by the Economic and Social Research Council and Natural Environment Research Council (ESRC-NERC). Hard language training funds were included.

At no other time during registration for the degree of Doctor of Philosophy has the author been registered for any other University award.

Relevant scientific and policy conferences and seminars were attended, external institutions were visited for consultation, and several academic papers are either published or under peer review by internationally academic journals.

Results were also disseminated in time for inclusion in public policy planning on Marine Protected Areas in Rodrigues Island (Mauritius) after acceptance by publications. A thesis copy will be submitted for filing post-examination in the public library of Rodrigues.

Peer-reviewed journal publications (rear cover)

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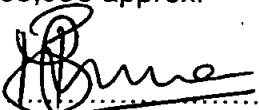
International Coral Reef Initiative (ICRI) Annual General Meeting, Seychelles, 25-27 April, 2005

Les Assises du Tourisme, Mauritius Tourism Promotion Authority, Mauritius 9-10th Feb. 2006

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CHAPTER ONE

INTRODUCTION

This chapter summarises the background, aims and objectives and principal research chapters of this thesis. It highlights key issues and clarifies the rationale, structure, contents and linkages between chapters as summarised at the end in Figure 1 (p.27).

1. Background

There is emerging recognition of two fundamental errors underpinning past policies for natural resource issues and awareness of the need for a worldwide change in the thinking and practice of environmental management (Hughes, Bellwood et al. 2005; Folke 2006). The first error has been an implicit assumption that ecosystem responses to human use are linear, predictable and controllable. The second has been an assumption that human and natural systems can be treated independently. The global collapse of fisheries (Roberts 2003; Roberts, Reynolds et al. 2006) and catastrophic change in states of tropical coral reefs (Scheffer, Carpenter et al. 2003; Bellwood, Hughes et al. 2004) are just two closely-related illustrations of both points at a time of rising natural drivers of change – notably climate (Hughes, Baird et al. 2003; Tompkins 2005; Sheppard 2006; Thatje 2006).

Marine Protected Areas (MPA) are being established at varying scales around the world often for related purposes - biodiversity conservation and fisheries management (Roberts, Branch et al. 2003; Balmford, Gravestock et al. 2004; Roberts, Hawkins et al. 2005). Tourism often benefits as a third driving force (Glover and Earle 2004) but there is concern that socioeconomic goals related to this and other kinds of development

may be prioritised in MPA contexts over protection of critical ecological goods and services upon which development and society ultimately rely. Tropical countries with rising coastal populations, and in particular small islands, face acute development pressures, while “sustainability” may easily be defined to allow short-term fixes perpetuating long-term degradation. Beyond clear biological benefits (Roberts, Bohnsack et al. 2001; Gell and Roberts 2003) MPA results on social levels remain mixed, with high rates of non-compliance (Kritzer 2004), and they may be context specific (Christie 2004; Oracion, Miller et al. 2005; Alcala and Russ 2006). More case studies may highlight new issues and allow comparisons leading to solutions. This is important in Africa, where conservation has a tainted history relating to narratives about the environment that do not stand up to scrutiny (Grove 1990; Adams and Hulme 2001).

2. Thesis aims and objectives

Two principal research questions addressed in this thesis relate to the need to treat humans as an integral part of social-ecological systems when planning Marine Protected Areas for sustainable development in small islands:

- 1) Are conservation and development compatible goals for MPA in small islands reliant on fisheries and tourism?*
- 2) Do social-ecological resilience concepts help clarify related issues of sustainability?*

Fieldwork was conducted in the small, remote sub-tropical island of Rodrigues, a semi-autonomous region of wider Mauritius. MPA are well established in similar tropical island reef fisheries, with varying emphases on ecosystem-based approaches to environmental management.

3. Chapter objectives and research approach

The thesis' two main aims are expanded in four core research chapters (3-6). Each considers a separate issue under-researched in MPA contexts. Chapters are linked by resilience concepts (summarised by Folke 2006; Brand and Jax 2007), which represent “a way of thinking” and a proposed benchmark for defining sustainability that takes account of local-to-global cross-scale and cross-temporal issues (Folke, Carpenter et al. 2002; Abel, Cumming et al. 2006). To summarise, chapters aim to:

- Identify and link the social, economic and ecological pressures facing Rodrigues, a semi-autonomous developing island of Mauritius. *This was approached by considering island-level societal responses to crisis and social-ecological change from a resilience perspective*
- Investigate cross-generational fishers' perceptions of state changes in local marine resources. *This was approached through identification of shifting baselines in fishers' cross-generational perceptions of the environment, and how such knowledge is relevant to MPA.*
- Determine tourist valuations of MPA relating to recreational use. *This was approached through contingent valuation, and a more general consideration of options and obstacles to tourism relating to MPA in small marginal islands.*
- Determine local stakeholders' perceptions and priorities relating to development and ecosystem health on Rodrigues. *This is developed in all chapters leading to a consideration of social and institutional constraints to MPA co-management.*

4. Structure

The determination of thesis aims and objectives is clarified further in the following literature review (Chapter 2). The first core chapter (3) then sets out the historical and recent context of the case study site and raises issues then addressed afterwards in

quantitative focal studies in chapters 4 and 5. Structural and other constraints to co-management of MPA are addressed in the final core chapter (6). Together, core chapters cover all stages of the “Adaptive Cycle” (Holling and Gunderson 2002) used to conceptualise collapse and recovery in social-ecological systems – within limits to its explanatory value proposed in Chapter 3. The summary chapter (7) is based on the Drivers-Pressure-State-Impact-Response framework (DPSIR). This is modified to describe small islands, from a version used in mainland Africa, (Mangi, Roberts et al. 2007). To develop policy indicators, DPSIR is used to address issues coinciding with the final stages of the Adaptive Cycle – reorganisation and (transformation). Overall conclusions, and indications of original contribution of research, are given in Chapter 8.

Methodologies used are specific to each chapter and are presented as such. The four core chapters are presented in journal publication format to allow rapid dissemination of findings to policy-making audiences. At the time of submission, one paper (4) was published* (Bunce, Rodwell et al. 2008), two were under review (3,5) and a fourth was in preparation (6). Published elements constitute Appendix 11 and there have been fed into MPA policy in the fieldwork site. The next section expands on chapter development.

5. Chapter development

The following summary introduces the four core chapters with abstracts, rationale and linkages. This section ends with a diagram of chapter linkages in Figure 1:

Chapter 3: Managing Collapse: Resilience and Sustainable Development in Vulnerable Small Islands

This chapter presents a broad overview of long-term trends in island degradation and policy-responses which may need to be understood to overcome barriers to social and

ecological change. Findings in this defining chapter form the basis for research and findings in all subsequent chapters.

Abstract

Keywords: natural hazards; adaptive management; livelihood; colonial history

Few studies consider how social-ecological systems recover from crises. This case study focuses on the remote, degraded Indian Ocean island of Rodrigues (Mauritius). Purposive semi-structured interviews (n=70) with key informants were completed during 12 months of fieldwork (2006) to elicit qualitative perceptions of island change and review policy responses. Secondary historical accounts and weather data were used to develop a timeline of events back to first settlement in the 1700s. To analyse results, we tested Holling's Adaptive Cycle (1973) as proposed as a model for conceptualising four stages of change from collapse to recovery.

Well before the 1970s, colonial stewardship (French then British) after human settlement by Europeans and African slaves in the 1700s had left Rodrigues' natural capital degraded (e.g. deforestation, soil erosion to the degraded lagoon) and vulnerable to natural hazards (cyclones, drought) and climate change. Interviewees identified a severe post-independence (1968) drought in the 1970s as the most pivotal crisis in living memory, catalysing what is proposed here as an island-level social-ecological collapse involving perhaps a state change. Farming plummeted, but fishing expanded rapidly with few controls and perverse incentives. Exponential population growth ended as migrants left for the main-island of Mauritius' booming economy. Rodrigues' high unemployment led to heavy financial dependence on Mauritius. Adaptive governance may help data-poor African islands and others determine options for recovery from future natural hazards along desired but more sustainable trajectories.

The Adaptive Cycle was of limited value in analysing social and ecological change, partly due to a shortage of reliable historical data for identifying its four phases. Another explanation could be that collapse and incomplete recovery simply progress in parallel rather than in cycle, with missed opportunities for breaking the trend. Regional autonomy for Rodrigues in 2001 was qualified by dependence on capital inputs from higher scales and inter-island differences. Mistrust between Creole Rodrigues' and Hindu-dominated main-island government pose risks to adaptive management at island and inter-island level. Marine and Coastal Protected Areas give scope for conserving natural capital as tourism demands expand. Adaptive governance may help data-poor African islands and others determine options for recovery from future natural hazards along desired but more sustainable trajectories.

Methodologies for research on social-ecological systems (Folke 2006) are still in exploratory stages (Walker, Carpenter et al. 2002), including coral reef contexts (Anon. 2007). Recent case studies (Abel, Cumming et al. 2006) highlight the policy relevance of identifying and understanding critical points of collapse and reorganisation in social-ecological systems, and adaptive governance to forestall and overcome crisis (Folke, Hahn et al. 2005). This may help islands (Tompkins and Adger 2004) limit risks of "knock-out" (Pelling and Uitto 2001) scenarios related to climate change (Payet 2006)

threatening their habitability let alone sustainable development. Some islands, such as Tuvalu (Pacific Ocean) already experience notable outward migration and risks of possible greater abandonment as climate change impacts upon natural resources underpinning local livelihoods. Despite such risks, resilience is rarely discussed for small islands (Brown, Adger et al. 2001; Abel 2003; Tompkins 2005).

MPA are a form of adaptive management related to sustainable development that can help islands build social-ecological resilience and perhaps develop away from crises along more desired trajectories. This chapter considers collapse and recovery of an island social-ecological systems using conceptual approaches used to review case studies in mainland Africa (Abel, Cumming et al. 2006). The chapter concludes that the resource limits of remote islands suggest the sustainable development paradigm may be illusory when considered beyond local scale, leaving achievable trade-offs and other policy options as options.

Chapter linkage: Two principal issues raised in this chapter are further explored in subsequent chapters – uncertainty over the extent and nature of ecological decline (4), and livelihood issues at the root of local ability to reduce fishing effort without perpetuating degradation in another ways or across scales (5). Both relate to building social ecological resilience may help both with MPA planning and building acceptance among local communities. Social and institutional constraints to cross-scale natural resource management raised in this chapter are discussed in detail later in Chapter 6 after these two issues of knowledge and livelihood are addressed.

Chapter 4: Shifting Baselines in fishers' perceptions of island reef fishery degradation

This chapter presents findings from an exploration of fisher's ecological knowledge of

fishery and wider island-level environmental degradation, indicating possible causes of degradation relevant to policy-making.

Abstract

Keywords –historical ecology; social-ecological systems; MPA; sustainable development

This chapter presents the first quantified evidence of shifting environmental baselines from an island-level coral reef fishery (Rodrigues). To survey the extent to which fishers perceive Rodrigues' fishery to be in decline 93 respondents from the three generations of active male fishers (18-29 years old, N=30, 30-49 years old, N=38 and 50-80 years old, N=25) were selected at random near landing stations representative of fishers and fishing methods around the island. Fishers identified from published fish guides any commercial species they believed to have been depleted during their lifetime (Saenz-Arroyo 2005). They also gave dates for the onset of each species' decline, and up to five reasons each for decline and how to stop it. Depletion of commercial fish species appeared to be spreading out from the coast, with a large majority (80%) of all ages of fishers seeing the lagoon fishery as already depleted and unable to meet local demand for fish. Youngsters shared few of their elders' memories of former abundance. Of three generations, the oldest reported more fish species as depleted ($p < 0.001$), including predators indicative of ecosystem health and of interest to fishers, and also marine tourists potentially paying fees to see them. The median number of species reported by the oldest group of fishers was 18, compared to 14.5 for the middle-aged and 8.5 for the youngest. The average number of years of decline cited per fish rose by around 5 years for each generation of fishers (Young=5 years, Middle Aged= 9, Old=15). For many individual species, especially grouper, older fishers stated far higher numbers of years of decline. In particular, older fishers recalled larger catches of the most-cited species, the grouper *Epinephelus multinotatus*, and bigger fish ($p < 0.001$). Based on their own perceptions, older fishers were more likely to have caught larger fish and landed more of them on their best day ($p < 0.005$ in both cases). Fishers cited a long-standing lack of work and fishery enforcement as the principle reasons for over-fishing and lagoon decline. Overall, older fishers remembered the ecosystem as being in better condition. They gave qualitative accounts of land-sea decline over decades supported this, but generations again differed again their perceptions of change, for example climate, deforestation, soil erosion and coral loss. Most saw reserves with fishing bans as necessary (87%), even though poorly-defined and implemented coastal reserves in the past had failed (88%). Shifting baseline studies may inform the planning of policy of Marine Protected Areas (MPAs) underway in Rodrigues and beyond in other data-poor countries prioritising sustainable development. Results presented here support findings from earlier shifting baseline studies in Mexico, but more studies are needed in different ecosystems and contexts to establish global trends and local needs for policy regulation, education and encouraging the better transfer of social memory down through generations.

Small oceanic islands with few livelihood options (Armstrong 2003) rely heavily on mixed reef fisheries. Bio-geographical isolation, lower biodiversity and higher endemism (Cronk 1997; Rees, Opdyke et al. 2005) means such islands may be especially less resilient to catastrophic ecological change (Holling, Carpenter et al.

2004). MPA implemented to reduce such risks may suffer from gaps in science useful to MPA policy decisions (Sale, Cowen et al. 2005). It has been suggested that where this remains the case the management and governance of complex adaptive systems may benefit from a combination of different knowledge systems (Johannes 1998, (Aswani and Hamilton 2004; Folke 2004). Such knowledge may be critically important in determining past environmental states and for reaching decisions on preferred future environmental states –steps critical to adaptive governance (Roberts and Hawkins 1999; Folke 2006). The phenomenon of “shifting environmental baselines” (Pauly 1995) may be a contributory factor to environmental degradation as it suggests each generation adjusts to increasing scarcity of fish and other resources and in so doing fails to understand the extent to which humans have modified their environment over the long term. However, social memory in the form of local environmental knowledge may easily be lost, for example, through migration. Such risks to social and economic development need to be addressed to build resilience.

Chapter linkage: Local knowledge emerges as a component of social ecological knowledge that may be useful in determining impacts of MPA and building support among resource users leading to compliance. By highlighting decline of large species with critical ecological function and of commercial interest to fishers and tourists this chapter demonstrates an incentive for protecting such species in MPA as a sustainable development option. Chapter 5 develops these issues in more detail, starting from the standpoint of a need to enhance the financial resilience of conservation.

Chapter 5: Tourist user fees for small island coral reef MPA

This chapter presents survey findings on tourists’ willingness to pay (WTP) to use land and marine protected areas (MCPA), and contextual qualitative findings from interviews with other stakeholders in natural resource management. WTP is not presented here as broad strategy for valuing ecological goods and services but as a practical policy

strategy for funding conservation in an economically dependent island seeking sustainable development.

Abstract

Key words: Divers, French-speaking, willingness-to-pay, ICZM, branding, development

French-speaking islands of the Indian and Pacific Oceans have reportedly low tourism fee-raising potential from their Marine Protected Areas (MPA), due partly to a lack of fee structures and poor management. This chapter addresses a lack of case studies of fee potential for such islands, focusing on the French-Creole speaking island of Rodrigues (Mauritius) in the Indian Ocean as it began setting up two types of MPA – one with a land element and four without. A survey of 351 tourists showed they were willing to pay 7 euro/week (median) to use a future Marine and Coastal Protected Areas with a large land element (McPA). Divers (167) among the visitors were potentially willing to pay more (depending on dive frequency) at 3 euros/daily to use a Marine (only) Protected Area (MPA) - regardless of any land element. Potential diver fee revenues (300,000+ euro) compare well with global benchmark MPA, for example at Apo island in the Philippines and Bonaire in the Caribbean. Fees could be levied at MPA but also potentially island-entry level as in Galapagos. However, diving is little developed. Visitor trip motivations were general, and focused more on nature, people and tranquillity than activities. Tourism is also dominated by French nationals with the lowest WTP compared to other visitors. The reasons for this were unclear, but not strongly correlated with low ratings of island environmental state. French tourists' comments suggested that their government's tradition of high taxes and centralised planning could be an issue creating resentment of "tax" overseas. More studies may reveal if this pattern is generalised. Overall, better access, a wider tourist base, mixed fees, insights into WTP motives and MPA-centred island branding for coastal management could help remote islands earn sustainable funding for conservation.

In Africa, as in Asia, the tourism sector has been a driver for MPA and ICZM establishment due to a recognized importance of biodiversity to tourists (McClanahan, Mwanguni et al. 2005), but funding remains a critical limiting factor for management of many African MPA in the Indian Ocean (Francis and Torell 2004). Local acceptance of MPA and Integrated Coastal Zone Management (ICZM) policies from various constituencies is likely to depend on degrees of economic benefits or resources they secure (Christie 2005). Some long-standing MPA appear to have achieved a "win-win" of fisheries benefits accompanied by tourism revenue (Alcala and Russ 2006), with coral reefs attracting rising numbers of paying divers (Green and Donnelly 2003).

This chapter addresses a gap in research on tourism funding for MPA in African French-speaking islands of the south-western Indian Ocean. Research questions

reflect the importance of linking land and sea protected areas (Carr, Neigel et al. 2003) to promote island-level resilience. This acknowledges that even when funds are secured for MPA, feed-backs of tourism can still exceed island social and environmental carrying capacities, reducing recreational amenity and revenue upon which it so often depends (Arrow, Bolin et al. 1995; Brown, Turner et al. 1997).

The chapter highlights potential but many constraints to tourism development and protected area fee generation. Bringing tourists' perceptions and island marketing strategies into ecosystem-oriented resource management frameworks (Walker, Carpenter et al. 2002) could help avoid the low WTP reported for various reasons in other MPA in nearby islands. However, island sustainability based on MPA is uncertain in the case study site as there is clear pressure for the main MPA to include a primary economic development commitment at local level, as in other African contexts (Francis and Torell 2004). Tourism in remote, resource poor islands may be possible only through significant input of capital from higher scales, raising doubts over sustainability. Equally, conservation may only partially slow biodiversity decline when protected areas serve multiple functions (Dietz 2003).

Chapter linkages: This chapter highlights a need for fishers' concerns and political realities to be addressed, or MPA-related tourism and WTP may have nothing to do with 'sustainability' in resilience terms (Casagrandi and Rinaldi 2002; Dietz 2003; Dietz, Ostrom et al. 2003). Qualitative findings highlight cross-scale issues of political will and island remoteness as potentially important determinants of MPA outcomes. Current island development trends and cross-scale management issues are developed in Chapter 6 as potentially critical determinants of MPA success in line with long-term perspectives raised in Chapter 3.

Chapter 6: Structural constraints to MPA co-management in small islands

This chapter returns to the point where broad-level contextual issues of resilience were left in Chapter 3. The chapter considers development trends in parallel with structural and social management issues from current islander perspectives. Together these raise risks of continuing degradation with or without MPA. Sustainable decisions may require multiple levels of decisions, but local resource users may fade from sight in the process in a top-down culture such as Rodrigues', leading to compliance issues. This chapter highlights lessons for Rodrigues from around the world with respect to the need to preserve capacity for self-organisation among resource users at lower scales.

Abstract

Keywords: Participatory management, networks, polycentric institutions, MPA, ICZM

Small island societies planning to move from degradation to sustainable development in resilience terms have a mixed record of success when using MPA. This chapter presents findings from a small Indian Ocean island planning Marine (and Coastal) Protected Areas (MCPA) to reduce external economic dependence through conservation and development linked to tourism. Devolution of power from Mauritius to regional government in its distant island of Rodrigues, is part of the process, with co-management planned for the main McPA. Semi-structured interviews with 70 key informants revealed commonly-held perceptions of drivers of degradation and prospects for McPA success as part of the solution. Influential stakeholders differed in their perceptions of island development needs and style, with institutional weakness, poor linkages and capacity emerging as potentially critical barriers to change. A lack of trust in private and public life emerged as a critical obstacle to adaptation, whether for planned or unplanned social, economic and ecological change. A further 93 fisher-farmers took part in a quantitative survey, giving closed and open-answer questions about their perceptions of causes of degradation and solutions. Causes included illegal fishing, linked to population pressure and unemployment. Enforcement, jobs and then MPA were identified as solutions. MPA risk being imposed with an overriding prioritisation of development over conservation. Tourism development may conflict with conservation. Agriculture, as a linked livelihood option, carries similar risks of degradation. Both are limited by and risk adding to water constraints typical in small degraded islands. Co-management urged by donors may take time to embed in societies used to openly flouting rules. Overall, cycles of island-level degradation may be perpetuated, with local resource users left to their traditional switching mix of fishing and farming or emigration. Case studies in resource management from other parts of the world may inform Rodrigues' plans, including strengthening capitals, reviewing tenure, and identifying winners and losers and policy trade-offs while preparing for instability and climate change.

For small islands short of local development options rapid expansion of tourism potentially offers a route out of dependency to a commercially successful economic

future. Such transformations often involve changing the scales and nature of cross-scale relationships (Kinzig, Ryan et al. 2006), and the emergence of a new kind of system – or a new way of “making a living” (Walker, Gunderson et al. 2007). Stakeholder participation (Stringer 2006), trade-offs (Brown, Adger et al. 2001) and better institutional linkages (Dietz, Ostrom et al. 2003) are proposed for balancing complex social, economic and ecological objectives along the way to building resilience using MPA. Studies in similar two-island states in the Caribbean suggest that the determinants of cross-scale interactions are the exercise of relative power between stakeholders, involving issues of domination, resistance, cooperation and access to information (Adger, Brown et al. 2006). Such relations between user groups (Armitage, Marschke et al. 2007) or their relative marginality (Hollup 2000) raise issues of equitable distribution of benefits in the context of coastal management in the tropics in an era of globalisation. For MPA, winners and losers emerge in efforts to blend conservation with tourism development (Oracion, Miller et al. 2005; Alcala and Russ 2006; Garnett, Sayer et al. 2007). In the case study site, water stress emerges as a related and pivotal issue (Pigram 2001; Pahl-Wostl, Craps et al. 2007) in determining whether new and/or revived development directions linked to MPA are “sustainable”.

Chapter 7: *DPSIR Indicators for Conservation and Development in Small Islands*

Chapters presented in this thesis are conceptually linked as shown in Figure 1. This is followed by a brief literature overview leading into the four core chapters, where the literature is developed more fully in context within chapters. Core chapters are conceptually summarised at the end in Chapter 7 with a view to linking findings to practical policy through the development of indicators. The summary recognises that measures of the conservation of benefits of MPA (Parish, Braun et al. 2003) need to be accompanied by measures of socioeconomic success (AidEnvironment 2003), while taking into account a wide variety of drivers, pressures, impacts and responses (Bowen

and Riley 2003). A modified DPSIR model is proposed for islands as part of the summary.

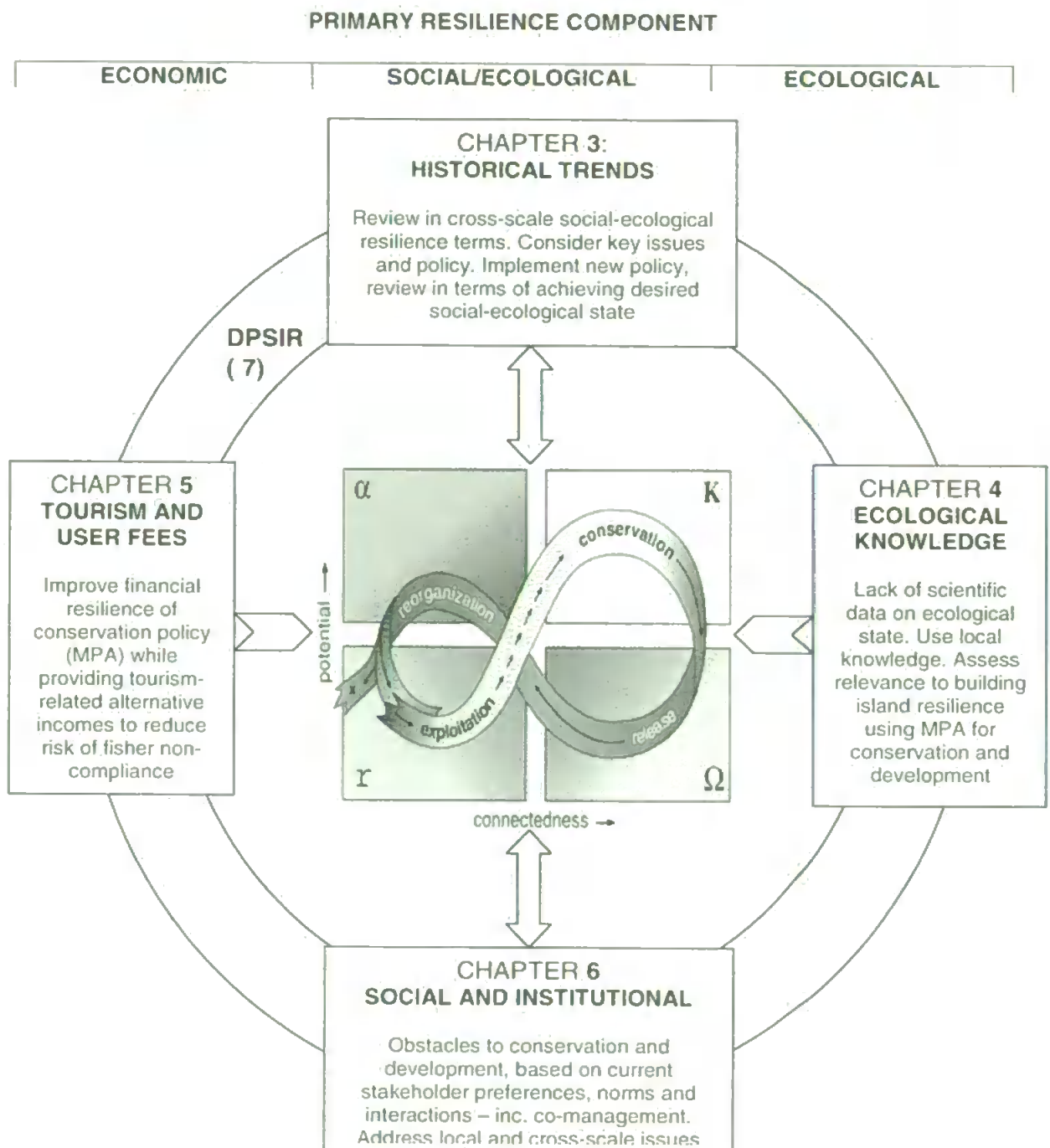
Abstract

Keywords: DPSIR, feedback loops, indicators, coral reefs, islands, fisheries, adaptive cycle

Small islands face increasing degradation due to cross-scale inter-linkages between human and natural pressure over land-sea interfaces. This paper summarises the case of Rodrigues Island, Mauritius, as it plans conservation and development policy using Marine (and Coastal) Protected Areas. The Driver-Pressure-State-Impacts-Response (DPSIR) conceptual model for classifying data is modified for reef island contexts to help policy-makers cope with planning for complexity. The model reflects the little control that small islands have over external natural variables, such as climate change. As modified here DPSIR can also reflect how many small islands have limited or no control over external social variables. Through a synthesis of this thesis and reference to other case studies a system of island-level indicators is then proposed for Rodrigues that may be relevant to tropical islands as they plan for MPA. Indicators may encourage linear views of resource management but DPSIR can be used at the same time to illustrate how policy can have unexpected impacts which feed back the system as existing or new drivers of degradation. DPSIR does not so easily address how these links may occur at different scales, and at different times, raising the risks of arbitrariness when setting limits to study boundaries. Overall, DPSIR analysis may be a useful policy tool for reducing island degradation, and moving island social-ecological systems move toward what Holling's conceptual Adaptive Cycle model (1973) describes as a phase of recovery. For MPA, this often involves reconciling conservation and development goals – a task usefully approached from a broad island perspective as a first step away from focusing too much on local MPA boundaries.

Final conclusions in Chapter 8 summarise key contributions to knowledge. Key research interview samples and transcripts are given in appendices 1 and 2. Copies of key databases are filed in the CD detailed in Appendix 3. Published journal articles and proof of submission of others are bound into the thesis (Appendix 11).

Figure 1: Conceptual linkage of chapters as issues arising and feeding back into policy analyses. Resilience (Chapter 3) concepts based on the figure-of-eight Adaptive Cycle (Gunderson and Holling 2002) help discover long-term issues and drivers of social-ecological resilience. The Drivers-Pressures-State-Impact-Response (Chapter 7) framework of issue classification helps to manage this on a faster policy cycle related to social and ecological state



CHAPTER 2

LITERATURE REVIEW

1. Introduction

This chapter identifies principal research questions forming the aims and objectives of this thesis summarised in Chapter 1. The questions raised sequentially relate to environmental policy paradigms, resilience, MPA, development, small islands, local knowledge, reef tourism, conservation financing and management institutions:

- Question 1:** Can MPA be used to achieve both conservation and development goals?
- Question 2:** Do resilience concepts and in the particular the adaptive cycle provide guidance in practical MPA policy-making contexts to answering Question 1?
- Question 3:** Can local knowledge usefully inform MPA policy for building resilience in data-poor island reef fisheries facing development pressure?
- Question 4:** Are tourist user fees a viable part of conservation and development strategy in remote tropical islands from a social-ecological resilience perspective?
- Question 5:** Are institutional factors a key constraint in small islands seeking conservation and development?

2. Global environmental degradation and Marine Protected Areas

There is recognition of two fundamental errors underpinning past policies for natural resource issues and awareness of the need for a worldwide fundamental change in thinking and in practice of environmental management (Hughes, Bellwood et al. 2005; Folke 2006; Roberts 2007). The first error has been an implicit assumption that ecosystem responses to human use are linear, predictable and controllable. The second has been an assumption that human and natural systems can be treated independently. The global collapse of fisheries (Roberts 2003; Myers 2005; Roberts, Reynolds et al. 2006; Shertzer 2007) and catastrophic change in states of tropical coral reefs (Scheffer, Carpenter et al. 2003; Bellwood, Hughes et al. 2004; Wilkinson 2006)

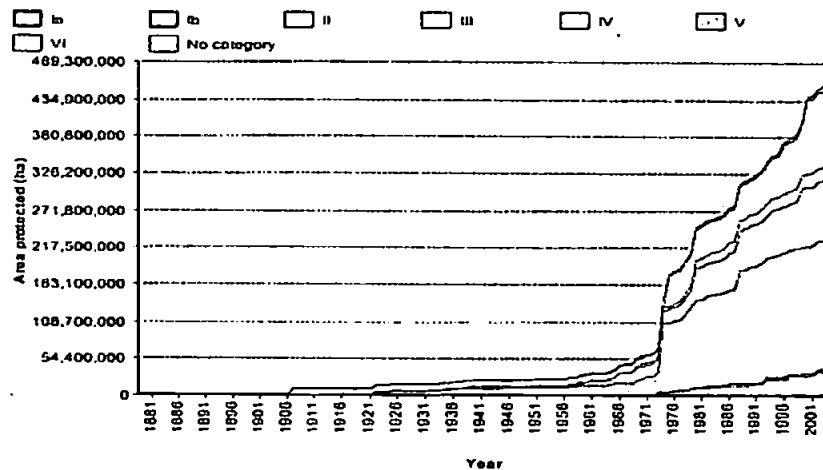
are just two closely-related illustrations of this at a time of rising natural drivers of change – notably climate (Hughes, Baird et al. 2003; Tompkins 2005; Sheppard 2006; Thatje 2006). There is an increasingly common view that new paradigms, perspectives, policies and governance systems are needed to safeguard ecological systems for societal development and future generations (Kinzig 2001; Hughes, Bellwood et al. 2005; Wallington, Hobbs et al. 2005). In practical policy terms:

"The loss of marine ecosystems can be translated into an economic loss in the short and long term and a loss of opportunity for future generations. Moreover, it represents a loss in the intrinsic value of the system and may have serious consequences in the provision of ecosystem services that are as yet unquantified." (EU 2003)

2.1 Marine Protected Areas

Marine Protected Areas¹ (MPA) broadly defined are at the centre of this debate (Roberts, Reynolds et al. 2006) despite knowledge gaps and related concern over their implications in terms of implementation and outcomes (e.g. Agardy, P. et al. 2003). The cross-scale use of MPA is proposed among other objectives for building coral reef and fisheries resilience (Costanza, Andrade et al. 1999; Hughes, Bellwood et al. 2005; Roberts, Reynolds et al. 2006). MPA have been established at varying scales around the world since evident fisheries declines in the 1950s and 1960s. The trend accelerated in the 1970s, leading to an almost a 10-fold expansion in reported MPA over the 30 years up to 2002 (Figure 2). Depending on objectives set for them MPA can be large or small, zoned for multiple use or not, continuous or networked, and either partly and/or fully based on no-take zones (NTZ) banning extraction of natural

¹ The variety of definitions and categorisations of MPA between nations and across academic disciplines has become confusing, with over 140 names for marine and terrestrial combinations identified around the world by IUCN/The World Conservation Union, whose own conservation-focused definition remains the most commonly accepted. Kelleher, G. and R. A. Kenchington (1992). Guidelines for establishing Marine Protected Areas. A Marine Conservation and Development Report. Gland, Switzerland, IUCN, UNEP-WCMC. (2005). "World Database on Protected Areas." Retrieved 24 February 2005, 2005, from <http://sea.unep-wcmc.org/wdbpa/>.

Figure 2 : Global growth of MPA (cum. ha) by category/area (UNEP-WCMC 2005)

resources (Halpern 2003; Roberts and Hawkins 2003). It is argued that a well-designed network of functionally– linked marine reserves (Roberts, Hawkins et al. 2005), when set within larger environmental management regimes, can provide a robust safety-net for conservation, with NTZ providing undisturbed control areas against which the effectiveness of adaptive management experiments can be measured (Roberts, Halpern et al. 2001; Roberts, Branch et al. 2003). In practical application, MPA also face tension in the relative weight accorded by planners and users to social compared to ecological goals. Against this background, the World Summit on Sustainable Development (2002) and the Convention on Biological Diversity (2004) backed the setting up of networks of MPA to conserve biodiversity and habitats. The IUCN and the World Parks Congress (2003) similarly called for 20-30% of marine habitats to be designated as fully-protected “no-take” zones (NTZ) by 2012 (IUCN 2003). Only 0.04%² of the seas had been designated as NTZ by 2005, against 0.5% for all types of MPA (UNEP-WCMC 2005). Although 20-30% remains highly ambitious MPA implementation continues, along with debate over their desirability, and ability to meet what may be perceived as conflicting social, economic and ecological objectives.

² Around 0.03% of this was due to an expansion of the world's largest MPA, the Great Barrier Reef Marine Park, in 2004

2.2. *“Win-win” conservation and development*

MPA (including fisheries reserves with or without NTZ) appear to have demonstrated benefits in fisheries and other ecological terms (Roberts, Bohnsack et al. 2001; Gell and Roberts 2003; Roberts, Hawkins et al. 2005), but in social terms impacts are presented as mixed and perhaps context specific (Christie 2004; Oracion, Miller et al. 2005), with high-rates of reported non-compliance (Dharmaratne, Yee Sang et al. 2000; Kritzer 2004; Depondt and Green 2006). MPA are not always set up by, or purposefully for, the general populace living in or around them, and yet MPA implementation can have a profound effect on these people's livelihoods (Garaway and Esteban 2003; Jobbins 2006). A shortage of peer-reviewed accounts of the social implications of MPA perhaps leaves them open to negative perceptions about who gains from their benefits (Gjertsen 2005; Oracion, Miller et al. 2005). The aim of ensuring that local communities do not suffer as a result of MPA implementation is reflected in the literature and built into international conservation agreements (Alcamo 2003; Mascia 2003; Gelcich 2005; Jones 2005; Spiterl and Nepalz 2005) which recognise humans as integral parts of ecosystems. However, Berkes (2006) points to the dissonance between what conservationists may consider to be a “community benefit” (for example, the sharing of financial benefits of ecotourism (Abel 2003; Tongson and Dygico 2004) and what multiple stakeholders in communities may consider to be benefits.

Local acceptance of MPA and Integrated Coastal Zone Management (ICZM) policies from various constituencies does appear likely to depend partly on degrees of economic benefits or resources they secure (Christie 2005; Christie, Fluharty et al. 2007). As on land, some long-standing MPA worldwide appear to have achieved a “win-win” of fisheries benefits accompanied by tourism revenue (Alcala and Russ

2006), with coral reefs attracting rising numbers of paying divers (Green and Donnelly 2003; Depondt and Green 2006). Others around the world have a less clear record (Dharmaratne, Yee Sang et al. 2000). In Africa, as in Asia, the tourism sector has been a driver for MPA and ICZM establishment due to a recognized importance of biodiversity to tourists (McClanahan, Mwaguni et al. 2005; Sobhee 2006). In East Africa, there is often pressure for conservation using Marine Protected Areas to include primary economic development commitments at local level (Francis and Torell 2004). However, tourism can clash with reef conservation, fisheries and other MPA goals, leaving other MPA stakeholders marginalised (Christie, McCay et al. 2003; Miller and Berno 2006).

"It is a well known phenomenon that local elites tend to capture the benefits from development interventions so a conservation-development project that starts with the aim to provide community benefits often ends up resulting in a less equitable distribution of power and assets" (Berkes 2004)

It has been suggested that basic research on MPA has focused too much on underlying natural science, while social factors, not just biological or physical factors, often determine the final success of an MPA (Christie, McCay et al. 2003; Christie 2004; Oracion, Miller et al. 2005). However, prioritising socioeconomic goals when setting MPA objectives goals and locations may undermine protection of critical ecological functions delivering goods and services upon which development and society ultimately rely (Roberts, Branch et al. 2003). Whatever local priorities may be, the use of larger, networked NTZ (Lauck, Clark et al. 1998; Lubchenco, Palumbi et al. 2003) is proposed for providing greater chances of enhanced, long-term flows of marine goods and services beyond their boundaries (Roberts, Bohnsack et al. 2001). Such claims in favour of MPA may be open to doubt (Sale, Cowen et al. 2005; Hilborn 2006) due to MPA science gaps and a perception that the benefits of other forms of fisheries regulation are being sidelined (Cinner, Marnane et al. 2005) by MPA. Even so,

there are strong arguments supporting a notion that conservation may serve only to partially slow biodiversity decline when protected areas serve multiple functions (Dietz 2003). More social and economic studies are needed, including comparative and long-term research, which includes social issues such as livelihood and population growth (Sheppard 2002; Sheppard 2003; Krishna 2007).

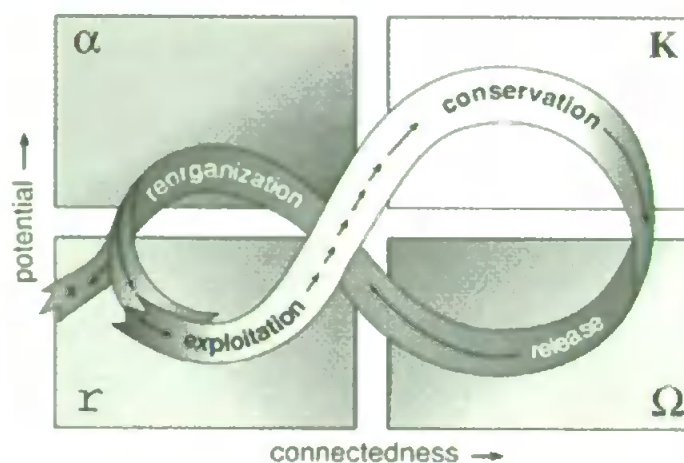
This is perhaps partly due to research difficulties stemming from the fact that social impacts and perceptions are dynamic and change rapidly. However, this only underlines a need to better understand cultural, social and economic factors at planning and implementation stages to help overcome community resistance and institutional failures at later stages (Bunce, Townsley et al. 2000; Pomeroy, Parks et al. 2004).

Question 1: Can MPA be used to achieve both conservation and development goals?

3. Resilience

MPA and issues of sustainable development are closely linked by concepts of resilience (Gunderson and Holling 2002). Resilience theory considering humans as integral parts of ecosystems (Berkes 2004) is well reflected in the literature on linked social-ecological systems (e.g. in <http://www.ecologyandsociety.org>) and relates well to resolving commons, common property and open-access resource issues (Hardin 1998; Dietz, Ostrom et al. 2003; Agrawal and Chhatre 2006). Resilience concepts (summarised by Folke 2006; Brand and Jax 2007; Walker, Gunderson et al. 2007) are represented as “a way of thinking” and proposed as a benchmark for “sustainability” that is broad enough to take into account increasingly relevant local-to-global cross-

Figure 3: The adaptive cycle (Holling and Gunderson 2002), showing (left) relationship between accumulation (r) and conservation of capital (K), its release (Ω) and re-organisation (α). Potential for resilience is reduced by exploitation (or accumulation) of capital and during release (or collapse phase Ω). Resilience may be rebuilt during phases of conservation and reorganisation. Whether social and ecological resilience are related is uncertain (Adger 2000). Components of resilience may have cycles at slower or faster rates, and/or at different scales. This may lead to interconnected multiples of Adaptive Cycles operating and feeding into each one another across time. Connectedness on a social level may refer to integration of management or trading systems, for example. On a natural level, it may refer to the patchiness of coral reefs, an attribute of resilience that may decrease with exploitation (r), be restored through conservation or degenerate if this fails as exploitation rises. Potential and connectedness have been simplified in other analyses by reference instead to a rise or fall (both axes) in capital – for example social, natural and financial capital (Abel, Cumming et al. 2006)



scale and cross-temporal issues (Folke, Carpenter et al. 2002; Abel, Cumming et al. 2006).

Resilience management approaches, often presented in the context of adaptive management (Folke 2006), represent a move away from what Walker, Holling et al (2004) refer to as “the presumed ability to predict probabilistic responses to management and external drivers such as climate” (Cherian 2007). Such ideas are usefully illustrated (Gunderson and Holling 2002) in the form of a figure-of-eight loop (Figure 3) representing four stages of Holling’s conceptual Adaptive Cycle proposed as model of how ecosystems progress through stages including build up and collapse.

The figure is based on an assumption of the existence, at some scale or scales, of the four principal phases that the elements of a system can cycle through:

1) entrepreneurial exploitation (r), organizational consolidation (K), creative destruction (Ω), and re- or de-structuring (α). The first two phases form a familiar, slow, fairly predictable pattern of growth called the "forward loop"; the second two constitute a less familiar, unpredictable, and, in ecosystems, more rapid "back loop" of reorganization. Together they make the cycle adaptive. Novel elements can accumulate, largely unexpressed, during the forward loop. Then, in the back loop, they become the seeds for the novel combinations that launch the next cycle. However, the ecosystem cycle is embedded in a set of those cycles that cross scales in space and time. Furthermore, such adaptive cycles in ecosystems occur in scales ranging from cells to biomes, with inter-linkages of increasing scale from centimetres to millennia (Holling, 2002).

Walker et al (2002) clarify the Adaptive Cycle with reference to drought in a rural Australian water catchment district. Using a timeline they outline key events, including external disturbance, which may have enhanced or reduced the capacity of the ecological system to support livelihoods in the social system. They propose phases of collapse and recovery in terms of policies or disturbance affecting the level of water run-off in farm land. This in turn was related to soil salt mobilisation and consequent scope for farming. Beyond a certain level of salinity in the natural system, livelihoods may be lost in the social system. Human capacity to organise to overcome and reverse situation is one indicator of resilience in the social system. However, the natural system may pass into an irreversible ecological state, such as over-fishing (and/or climate change) leading to loss of live coral cover in a reef and domination by grazing urchins and algae (Hughes, Bellwood et al. 2005). Such a shift in "state" representing loss of ecological resilience to disturbance may translate into a long-term collapse of the fishery, lost livelihoods and reduced capacity to cope with future disturbance in the social system. The ability of people to adapt to such change may be increasingly limited, leading to loss of livelihood and social breakdown. Again in a fisheries context,

Seixas and Berkes (2003) use the Adaptive Cycle to describe change in a lagoon fishery enclosed by a naturally opening and closing channel through a sand bar. Exploitation and conservation here are characterised by increasing biomass and raising water levels (compared to the sea). As the channel opens brackish water enters and fish and shrimp leave. Renewal is described by rising salt water, and renewing stocks of mature and immature fish, and shrimp larvae, entering the lagoon before the channel closes up again. Management practices affecting the lagoon – whether enforcement or gear choice, for example – are categorised into phases of the Adaptive Cycle over the decades, depending on their impacts.

Proponents of resilience concepts criticise the weakness of current approaches which typically measure the health of an ecosystem by monitoring abundances of a few conspicuous species, or species resilience, as opposed to functional resilience. In the process, little regard is given to the driving temporal or spatial variation in abundance, or the consequences of changes in these few species to the whole ecosystem. Resilience management on the other hand is based upon retaining the functionality and response diversity of a system when it is perturbed, or maintaining the elements needed to renew or reorganize if a large perturbation radically alters structure and function (Walker, Carpenter et al. 2002). New frameworks for adaptive governance, based on social and ecological resilience concepts, rely on an ability to detect and react to ecological feedbacks (Walker, Carpenter et al. 2002; Hughes, Bellwood et al. 2005). This is increasingly viewed as necessary, as feedbacks from damaged ecosystems in the global marketplace may be masked by the sale of natural capital. Hughes et al (2005) summarise four steps towards social-ecological resilience approaches to adaptive management of marine resources:

- Embracing uncertainty and change
- Building knowledge and understanding of resource and ecosystem dynamics

- Developing management practices that measure, interpret and respond to ecological feedback
- Supporting flexible institutions and social networks in multi-level governance systems

Scenario development exercises relating to management of changes in and around northern U.S. lakes show how apparently rational choices can still lead to the failure of multi-state ecosystems (Peterson, Beard Jr. et al. 2003; Peterson, Carpenter et al. 2003). Even cases of apparent simplicity may have drivers at different spatial and temporal scales which are hard to perceive at local level (Berkes 2004). Interdisciplinary perspectives based upon the organizing concept of resilience provide a metaphor (Walker, Carpenter et al. 2002) for bridging the traditional divide between social research, which focuses on institutions, organizations, and social practices, and ecological research, which focuses on the cross-scale dynamics of ecosystems (Anderies, Janssen et al. 2004). There is some suspicion over such ecosystem-based approaches to natural resource management. (Murawski 2007). However, the intricate thinking behind resilience has gained attention as a philosophical framework. Resilience is of direct relevance to using MPA within hierarchical management structures able to address contextual cross-scale issues including land-based activities and climate threatening to undo the best of local conservation efforts (Cicin-Sain and Belfiore 2005; McClanahan, Mwangi et al. 2005). MPA are already used in broad ecosystem conservation (De Leo and Levin 1997) from extensive island groupings to the high seas (Berkes 2004). However, resilience is less considered in the context of MPA beyond well-developed ecological applications (Roberts, Branch et al. 2003; Basketta, Michelib et al. 2007).

Recent analyses of land-based natural resource management case studies (Abel, Cumming et al. 2006) highlight the policy relevance in African contexts of

understanding critical points of collapse and reorganisation in social as well as ecological systems Together with adaptive governance this may help to forestall and overcome crises (Folke, Hahn et al. 2005). With this in mind:

Question 2: Do resilience concepts and in the particular the adaptive cycle provide guidance in practical MPA policy contexts to answering Question 1?

4. Identification of research questions guiding aims and objectives

4.1 Small islands

Tropical countries with rising coastal populations, and in particular small islands, face acute development pressures (Pelling and Uitto 2001; Armitage and Johnson 2006). Small tropical islands in particular also face tight feedback loops between environmental stressors and drivers on land and sea (Kerr 2005). Together with the bio-geographical isolation of remote islands, and their lower biodiversity and higher endemism (Cronk 1997; Rees, Opdyke et al. 2005), this leaves them less resilient to catastrophic ecological change (Holling, Carpenter et al. 2004). Islands face rising risks of “knock-out” scenarios, which may in future be related to climate change (Payet 2006) (Tompkins and Adger 2004) (Pelling and Uitto 2001). These are scenarios which relate to the well-known but distant history of Easter Island but in more modern and perhaps instructive contexts to the two-state island of Haiti and the Dominican Republic. Diamond (Diamond 2005) in his review of how societies “choose” to collapse questions the future viability of “no hope” islands such as Haiti, whose population depends increasingly on ecosystem goods and services beyond borders, and migration for employment to help prop up a failed economy: “Haiti is so poor, and so deficient in natural resources and in trained and educated human resources that it is really difficult to see what might bring about improvement” after extensive degradation of forests and other ecosystem components still intact beyond border sufficiently for Dominicans to

prosper by comparison. The limited capacity of one half of the island to help the other, and the extent to which it may choose to do so, underlines the critical role of human decisions in such crises, and issues of ethnicity. Risks of climate change eroding the basis of social-economic activity are acute for small and remote coral islands, where coral is less likely to recover after increasingly common bleaching events (Hughes, Baird et al. 2003) due to a lack of larval supply. Small islands are particularly vulnerable to damaging El Niño-related climate fluctuations leading to severe drought and water shortages (Pelling and Uitto 2001), for example Fiji and Tuvalu. Sea-level rise, coral bleaching, water stress and saltwater intrusion, heat stress on crops and rising disease may add to multiple and sequential stresses to island social-ecological systems to the point of no longer supporting human habitation even under moderate climate change scenarios (Barnett and Adger 2003). The case of Tuvalu, in particular, is another recent case study of risks of potential for “knock-out” scenarios through recent debate over its future inhabitability and the possible need for mass migration to other countries (Leslie 2004; Yamano, Kayanne et al. 2007). Detailed historical analysis (108 years) and reconstruction of past land-forms showed Tuvalu is highly vulnerable to elevated sea level caused by extreme events and global warming. This is partly due to original landform characteristics but also construction on swampland since 1970s inward-migration following independence (Yamano, Kayanne et al. 2007). The high island vulnerability of such islands may be raised further by tsunami, accentuating seasonal island shoreline changes (Kench, Nichol et al. 2008). The extent to which a social system may collapse compared to observed ecological damage, however, is debated, and may be political, as perceived by some in the extent of Tuvalu’s requests for emigration visa priority and emergency funds (Leslie 2004). Overall, “the point at which sovereign atoll countries become effectively uninhabitable clearly constitutes a dangerous level of climatic change”, with large numbers of people potentially exposed to single events as in the Maldives (Barnett and Adger 2003). Migration which in the

past has sustained island resilience may in future cross thresholds that ensure that it is undermined, for example through loss of social capital. Building island-level resilience may help such vulnerable societies limit such risks but resilience is rarely discussed for small islands (Brown, Adger et al. 2001; Abel 2003; Tompkins 2005). Islands are often considered more from vulnerability (Gowrie 2003) and Small Island Developing States (SIDS) viewpoints which do not address the risk of “sustainability” being construed to allow short-term fixes perpetuating long-term ecosystem degradation. Small tropical islands present a useful context for considering MPA at early planning stages from a resilience perspective.

***Issue:** Island-scale case studies may in resilience terms provide guidance to sustainable development using MPAs in small tropical islands.*

4.2 Small island reef tourism

Development options in small islands are limited (Armstrong 2003). Beauty and biodiversity help coral reef systems provide humans with renewable and non-renewable ecological goods and services (Moberg and Folke 1999). Threats to reef survival worldwide from land and sea include distortion of food webs from above, including over-fishing, and addition of nutrients from the bottom, leaving climate change, new diseases and “other human-caused impacts” to do the rest (Hughes, Bellwood et al. 2006). Such risks include tourism. Beyond the two main related purposes of MPA - biodiversity conservation and fisheries management (Roberts, Branch et al. 2003; Balmford, Gravestock et al. 2004; Roberts, Hawkins et al. 2005) - tourism often benefits as a third driving force (Glover and Earle 2004; AOSIS 2005). Marine and coastal tourism is one of the world's fastest growing activities. Expansion in nature-based tourism exceeds tourism's globally upward growth trend (Nyaupane, Morais et al. 2004). Exponential growth of tourism has spread to the remotest regions

of the world, raising paradoxes in nature tourism (Hall 2001; Hillery, Nancarrow et al. 2001). Tourists seek recreational amenity on reefs (Depondt and Green 2006), of which 75% are in developing countries (Wilkinson 2006) and where there is pressure on reefs from growing populations already heavily dependent of them for food and livelihood. Of the 31 countries with over 20% of their Gross Domestic Product (GDP) generated by travel and tourism, 27 are island states. Islands contain 12 of the world's 18 global centres of endemism for coral reefs and seven of the world's global coral reef hotspots (Lutchman 2005). Islands with fringing reefs are particularly prone to development risks (Gomez 1997).

Issue: The "sustainability" of coral reef-related tourism may be clarified in resilience terms.

4.3 MPA science gaps and local knowledge

MPA implementation is particularly advanced in coral reef contexts. However, this process often suffers from gaps in science useful to MPA policy decisions (Sale, Cowen et al. 2005). This is particularly so in developing countries where reefs are mostly found.

Whether or not this should be considered an obstacle to MPA implementation, it has been suggested that the management and governance of complex adaptive systems may benefit from a combination of different knowledge systems (Johannes 2000; Aswani and Hamilton 2004; Folke 2004). Such knowledge may be critically important in determining past environmental states and for reaching decisions on preferred future environmental states – steps critical to adaptive governance necessary for social-ecological resilience (Roberts and Hawkins 1999; Folke 2006). However, such knowledge may be misleading – or flawed. The phenomenon of "shifting environmental baselines" (Pauly 1995) suggests successive generations of fishers adjust to

increasing scarcity of fish and fail to understand the extent to which humans have modified their environment over the long term. This is an important point when serious doubts are already expressed over the possibility of managing reef fisheries in developing countries with 75% of the world's coral reefs, rich reef biodiversity, and growing populations of people dependent on both for their food and livelihood:

"Coral reefs are under dual attack, with global climate change threatening further damage, and current levels of subsistence and commercial fishing increasing. Thus there is little chance of 'sustainable reef fisheries' when the pressures keep mounting exponentially and the likely future scenario is total depletion of many stocks with localised extinctions of some species" (Pauly, Christensen et al. 2002).

It is possible that shifting baselines (Pauly 1995; Saenz-Arroyo 2005) are present in island reef fisheries. This thesis addresses the hitherto current lack of quantitative evidence to allow a full discussion of its policy implications, in terms of the prospect of collapse of reef fisheries and implications of both for island reef tourism.

Questions 3: *Can local knowledge usefully inform MPA policy for building resilience in data-poor island reef fisheries facing development pressure?*

4.4 Financing conservation

There are increasing calls for reefs to be protected from fisheries pressure but also tourism impacts. Since coral reefs and beaches associated with tourism cannot be assigned value as easily as wet-fish on a landing jetty, basic economic theory suggests that rational decisions cannot be made with respect to sustainable conservation and management of relevant ecosystems. However, attaching value to natural resources has been a priority strategy in attempts to limit environmental degradation in complex systems such as developing tropical islands (Limburg, O'Neill et al. 2002; Spurgeon 2006; van Beukering, Brander et al. 2007). This has been applied directly to aspects of biodiversity of most interest to tourists with a view to generating income in the form of protected area user fees (Cesar 2000; Dixon, Scura et al. 2000; Rudd 2000). A

common format for doing this has involved the use of Contingent Valuation Methods (CVM) (Splash 2000; Arin and Kramer 2002). Although criticised by some from broad social, cultural and economic perspectives (Chiesura and de Groot 2003; Smith and Wilen 2003; Sagoff 2004) such valuations and fees are among the few options usually considered for locally-funding MPA that have been put into effect with reported success (Alcala and Russ 2006). The valuation of marine parks themselves has been considered in the Seychelles where CVM has recently revealed a WTP of \$5 above the normal cost of a snorkelling or diving trip (Cesar, van Beukering et al. 2004). The place of Contingent Valuation Methods and Revealed Preference Techniques (for example Travel Cost - TC) in determining in the context of Total Economic Valuation (TEC) of the environment remain subject to intense debates over the extent to which monetary value can be assigned to Natural Capital or even reveal 'welfare'. The use of stated preference techniques such as CVM, and in particular willingness-to pay in a reef context, have been reviewed by Spash (2000). CVM has been applied in scenario-building and trade-off analyses in Tobago aimed at establishing equivalent surplus measures of welfare changes related to alternative policies on MPA use (Brown, Adger et al. 2001). Issues of willingness to pay and the need for a balance between development and conservation raise concerns over equitable spread of proceeds of conservation and development at local level:

"Economic valuation can help improve coral reef conservation and management, but the level of detailed valuation required depends on the use (that) the value estimates will be put to and on the management objective addressed. It will depend on whether a "top-down" centralized decision making process is appropriate or a "bottom-up" community-based decision-making process is to be used" (Lal 2004).

Turner et al (2000) illustrate the place of economic valuation within boundary interfaces proposed between ecological conditions and economics in coastal zones (Appendix 4).

The World Conservation Union has long recommended the relevance of economic valuation and “the need to ensure that resource users pay the full social costs of the benefits they enjoy” - as attempted for local communities in Africa, (Emerton 1998; Emerton and Tessema 2000; Emerton 2003). However, such fees may not be an option in the world's most remote regions (Depondt and Green 2006) leaving them with questions over how to fund conservation, with or without tourism for development.

Question 4: Are tourist user fees a viable part of conservation and development strategy in remote tropical islands from a social-ecological resilience perspective?

4.5 Institutions

MPA are a form of adaptive management related to sustainable development that may help coastal communities to build social-ecological resilience and in so doing perhaps develop away from crises along more desired trajectories. The importance of social norms and institutions in determining the outcomes of conservation and development policy is well-reflected in recent literature. Finding a workable match between institutions and ecosystems, and for perspectives that may be held by different agents, (Berkes 2004) presents challenges. In resilience terms, transformation of society towards new social-ecological configurations often involves changing the scales and nature of cross-scale relationships (Kinzig, Ryan et al. 2006). Such steps may need to overcome relative differences in power between stakeholders (Adger, Brown et al. 2006), promote learning (Armitage, Marschke et al. 2007) and reduce marginality (Hollup 2000). This could help to improve prospects for acceptable distribution of benefits in the context of coastal management in the tropics in an era of globalisation. However, there is often a problem reconciling top-level policies of conservation with local aspirations (Carew-Reid 1990; Kellert, Mehta et al. 2000; Oracion, Miller et al. 2005)

A study of the political economy of conservation in four African countries (Gibson 1999) showed that the forces operating at the level of the nation state (many of them related to the peculiarities of postcolonial governments) are quite different to those at the levels of region and community³. Stakeholder participation (Stringer 2006), trade-offs (Brown, Adger et al. 2001) and better institutional linkages (Dietz, Ostrom et al. 2003) are proposed for balancing complex social, economic and ecological objectives along the way to building resilience using MPA. There is a need for a better understanding of community-based conservation management schemes, including patterns of success and failure (Francis, Nilsson et al. 2002) across many sites, in order to prevent them being hastily discarded (Pollnac and Crawford 2001). Direct enforcement of conservation decisions taken at higher levels may lead to less community cooperation and ultimately failure, particularly if poverty-degradation cycles prove persistent. A deeper understanding of such social-ecological interactions implies more attention to cross-scale conservation, adaptive co-management, incentive and multiple stakeholder issues, the use of traditional ecological knowledge and the development of cross-cultural conservation ethics (Berkes, Colding et al. 2003; Berkes 2004). However, links between the social and environmental systems (Folke, Carpenter et al. 2002) have been more usually considered in land than marine contexts, even though land, coastal and open sea ecosystems are increasingly seen as inextricably linked and in need of integrating management approaches (Çiçin-Sain and Belfiore 2005).

Question 5: Are institutional factors a key constraint in small islands seeking conservation?

³ Defined in terms of communities as multidimensional, cross-scale, social political units or networks changing through time, following Carlsson, L. (2000). "Policy networks as collective action." Policy studies journal 28: 502-520.

5. Summary

This section has reviewed literature relating to MPA directly or indirectly, highlighting policy issues for their research relevance. The first two questions are raised as thesis aims, followed by other questions forming broad objectives developed separately in following chapters. Beyond gaps in the literature, consideration of which issues to prioritise also took into account the funding mandate of this thesis (ESRC-NERC) to produce outcomes considered to be useful in application to policy-makers, in this instance the Office of the Prime Ministers' of the Republic of Mauritius and Chief Commissioner of the Rodrigues' Regional Assembly (RRA).

CHAPTER 3

MANAGING COLLAPSE: RESILIENCE AND SUSTAINABLE DEVELOPMENT IN VULNERABLE SMALL ISLANDS

Keywords: Africa; natural hazards; adaptive; coral reef; livelihood; fisheries; colonial history

1. Abstract

Few studies consider how social-ecological systems recover from crises. This case study focuses on the remote, degraded Indian Ocean island of Rodrigues (Mauritius). Purposive semi-structured interviews (n=70) with key informants were completed during 12 months of fieldwork (2006) to elicit qualitative perceptions of island change and review policy responses. Secondary historical accounts and weather data were used to develop a timeline of events back to first settlement in the 1700s. To analyse results, we tested Holling's Adaptive Cycle (1973) as proposed as a model for conceptualising four stages of change from collapse to recovery.

Well before the 1970s, colonial stewardship (French then British) after human settlement by Europeans and African slaves in the 1700s had left Rodrigues' natural capital degraded (e.g. deforestation, soil erosion to the degraded lagoon) and vulnerable to natural hazards (cyclones, drought) and climate change. Interviewees identified a severe post-independence (1968) drought in the 1970s as the most pivotal crisis in living memory, catalysing what is proposed here as an island-level social-ecological collapse involving perhaps a state change. Farming plummeted, but fishing expanded rapidly with few controls and perverse incentives. Exponential population growth ended as migrants left for the main-island of Mauritius' booming economy. Rodrigues' high unemployment led to heavy financial dependence on Mauritius.

The Adaptive Cycle was of limited value in analysing social and ecological change, partly due to a shortage of reliable historical data for identifying its four phases. Another explanation could be that collapse and incomplete recovery simply progress in parallel rather than in cycle, with missed opportunities for breaking the trend. Regional autonomy for Rodrigues in 2001 was qualified by dependence on capital inputs from higher scales and inter-island differences. Mistrust between Creole Rodrigues' and Hindu-dominated main-island government pose risks to adaptive management at island and inter-island level. Marine and Coastal Protected Areas give scope for conserving natural capital as tourism demands expand.

2. INTRODUCTION

Issues of how people respond to change catalysed by external stress, and how society reorganizes afterwards (Gunderson and Holling 2002), have critically determined whether some past societies survived or collapsed (Diamond 2005; Abel, Cumming et al. 2006). Coastal ecosystems with rising populations are particularly subject to

feedback effects between social and ecological elements as they face intense environmental change (Turner 2000; Adger, Hughes et al. 2005). Small islands are often most exposed to such risks and impacts (Pelling and Uitto 2001; Cherian 2007). Some islands have in the past proved resilient to social and ecological disturbance (Bayliss-Smith, Bedford et al. 1988), but this may change (Barnett and Adger 2003). For example, coral reefs at the core of social and ecological systems are globally threatened and face collapse (Holling 2000; Scheffer, Carpenter et al. 2003). Most are located in tropical islands, which have poor conservation records (Barrett, Brandon et al. 2001; Payet 2004). The need to understand island vulnerability – or susceptibility to damage (Pelling and Uitto 2001) - in terms of physical and structural components of risk (economic, political, institutional and environmental) is recognised (Gowrie 2003; SOPAC 2003). How vulnerability relates to sustainability (Adger 2006) has been less discussed and remains unclear due to varying definitions and agendas (Kerr 2005).

2.1 Resilience

Resilience concepts (Brand and Jax 2007) focusing on dynamic change and adaptation – or potential for recovery from damage – are proposed as a replacement of the sustainable development paradigm focused on “lifestyle and production” (Abel, Cumming et al. 2006). Recent reviews of resilience (Folke 2006) and case studies (Abel, Cumming et al. 2006) highlight the policy relevance of identifying and understanding critical points of collapse and reorganisation in social-ecological systems, and adaptive governance to forestall and overcome crisis (Folke, Hahn et al. 2005). Building social-ecological resilience (Folke, Carpenter et al. 2002; Folke 2006) in islands (Tompkins and Adger 2004) may help them limit risks of “knock-out” (Pelling and Uitto 2001) scenarios related to climate change (Payet 2006) threatening sustainable development. This could include low lying atolls becoming uninhabitable due to climate change impacts on critical ecological goods and services of already highly vulnerable small islands (Barnett and Adger 2003) such as the Maldives or

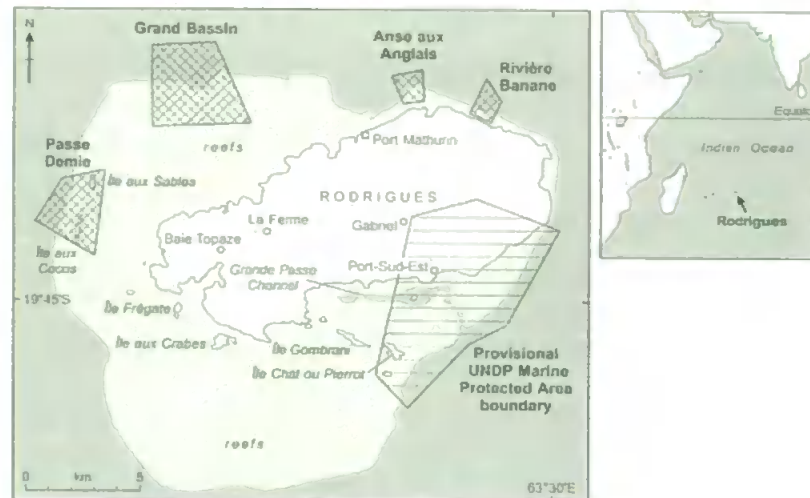
Tuvalu. However, with few exceptions (Brown, Adger et al. 2001; Abel 2003; Tompkins 2005), resilience is rarely discussed in the context of small islands, which are considered more from vulnerability (Gowrie 2003) and Small Island Developing States (SIDS) paradigms, with less attention to non-state islands and regions (Kerr 2005). The few studies that focus on the impacts of natural hazards on SIDS tend to focus on the short-term and relate more to economic than social and environmental aspects, or links between them alone (Meheux 2006). Causes and implications of impacts of hazards, particularly indirect, are often not considered and those specific to islands in general may be overlooked. Small and marginal "sister" islands within island states may be particularly at risk as they are often seen as a burden (van Beukering, Brander et al. 2007) and receive fewer financial resources. Such recognised gaps carry risks of poor adaptive response to crises and raise risks of social-ecological collapse (Diamond 2005).

2.2 Aims and objectives

This chapter aims to identify periods of crises and societal response in a degraded small island region where "sustainable" development policies focus on fishing, farming and tourism coupled with new conservation plans based on Marine Protected Areas. In doing so this chapter considers the relevance the adaptive cycle (Abel, Cumming et al. 2006) as a conceptual analytical tool in an small island context. The remaining sections set out to:

- Synthesise and add to island history to identify trends leading to what may be phases of collapse and renewal in the adaptive cycle
- Identify points of disturbance and windows of opportunity for building resilience
- Elicit decision-makers' perceptions to identify possibly contributory variables and policies influencing the trajectory of Rodrigues before and after "collapse"
- Consider some of the plausible alternative island configurations for the case study island
- Discuss the relevance of the adaptive cycle for understanding data-poor islands

Figure 4: Map showing location of Rodrigues. Boxes show locations of marine reserves and a Marine Protected Area (The lagoon reef flat is denoted by the light grey area in the map marked 'reefs')



2.3 Research site

The small island of Rodrigues (18.3 km long by 6.5 km wide) lies at 19°4'S, 63°25'E in the inter-tropical zone of the south-western Indian Ocean 600 kms east of the of central government in the main island of Mauritius (McDougall, Upton et al. 1965). The island's (104 sq km) steep volcanic flanks and deep narrow valleys, rise to a central east-southwest ridge peaking at 398m (McDougall, Upton et al. 1965). Surrounded by the Indian Ocean's largest reef lagoon (200 sq m), Rodrigues is among South Mascarene Islands collectively ranked highly in terms of existence and threats to their marine endemism (Kelleher, Bleakley et al. 1995; Hardman 2006). The historical state of isolated Rodrigues is unclear in timing and detail (North-Coombes 1971; Oliver P.G. 2004). Rodrigues' marine natural resources are known to be poorly documented (Chapman and Turner 2004) and there is a general view that land degradation was closely linked to marine degradation and that both were severe (Oliver and Lynch 2004). As in the more developed main island of Mauritius (Bhikajee 2001), human and natural pressure (Hardman, Meunier et al. 2004) is rising in Rodrigues' coastal zone, with tourism developing and fishing expanding outwards (KPMG 2006). Biodiversity management is weak (Anon. 2005) and environmental management "unsustainable"

Chapter 3: Managing Collapse: Resilience and Sustainable Development in Small Islands
(Anon. 2003). Rodrigues' recent semi-autonomy (2001) make the island a useful case study in resilience terms of how humans perceive and adapt to change in environmental state in the context of establishing new Marine and Coastal Protected Areas. Beyond natural sciences the island is barely researched and the wider literature on Mauritius generally makes little or no mention of Rodrigues and its completely different realities.

3. METHODOLOGY

3.1 Terms

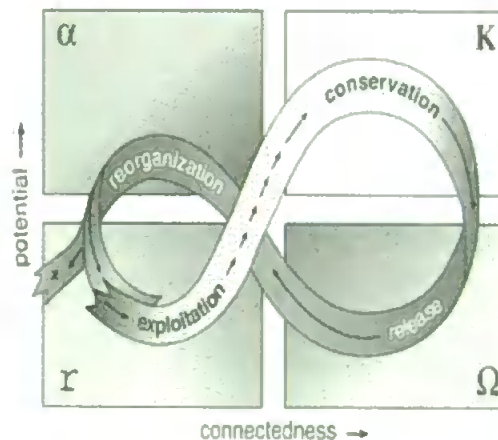
Resilience concepts (Brand and Jax 2007) are variously defined but constitute at least a boundary concept or "way of thinking" able to link social and ecological systems, or interpret complexity (Anderies, Walker et al. 2006; Folke 2006). This chapter refers to hybrid definitions of "resilience" as a property of social-ecological systems reflecting (Walker, Carpenter et al. 2002; Folke 2006):

- Amount of change a system can take while keeping the same controls on function/structure
- Extent of a system's ability to self-organise
- Ability to build and increase the capacity for learning and adaptation

Of specific relevance to this study, resilience management therefore aims to (Walker, Carpenter et al. 2002):

- Prevent the system from moving to an undesired configuration in the face of external stress and disturbance and,
- To nurture and preserve elements that enable the system to renew and reorganise itself following a massive change

Figure 5: The adaptive cycle (Holling and Gunderson 2002), showing relationship between accumulation (r) and conservation of capital (K) and its release (Ω) and re-organisation (α). Potential for resilience is reduced by exploitation (or accumulation) of capital and during release (or collapse phase Ω). Resilience may be rebuilt during phases of conservation and reorganisation. Whether social and ecological resilience are related is uncertain (Adger 2000). Components of resilience may have cycles at slower or faster rates, and/or at different scales. This may lead to interconnected multiples of Adaptive Cycles operating and feeding into each other across time. Connectedness on a social level may refer to integration of credit and trading systems, on a natural level the patchiness of coral reefs, an attribute of resilience that may decrease with exploitation (r), be restored through conservation and degenerate if this fails.



Research approach

Methodologies for research on social-ecological systems (Folke 2006) are still in explorative stages (Walker, Carpenter et al. 2002), including coral reef contexts (Anon. 2007). We adopt an approach to resilience used to consider collapse and recovery of social-ecological systems in mainland Africa (Abel, Cumming et al. 2006). Abel et al. used Holling's four-stage Adaptive Cycle to review processes of change in various ecosystems described in earlier studies (Figure 5). Resilience in terms of human accumulation of capital expected to start rising in r , grow more rapidly in K (*the fore-loop*) then collapse in Ω and stay low in α (*the back-loop*) before rising again in r . Walker et al define the move from Ω to α as a stage when the system changes rapidly, with a susceptibility to loss of social, economic or natural capital (Box 1), and a possibility for novelty to enter. Measures to conserve such capital are appropriate during this phase due to system vulnerability to entering undesirable configurations. Influential ideas (good and bad) may become entrenched and guide the evolution of

Box 1: Definitions of capital in social-ecological systems (adapted from Abel, Cumming et al. 2006)

<i>Social: social networks, formal and informal rules mediating interactions between humans, humans-environment. Includes cultural, institutional, bonding (between similar individuals) and bridging capital (between unlike groups)</i>	<i>Human: knowledge/skills/competences/attributes embodied in individuals that promote creation of personal/social/economic well-being</i>
	<i>Natural: the ecosystems that support humans</i>
	<i>Physical: technology and infrastructure</i>
	<i>Financial: access to money</i>

the system. Cycles (fast and slow) may interact across scales (Figure 5) in the wider local-to-global social-ecological system (Gunderson and Holling 2002).

The adaptive cycle is increasingly adopted as an analytical tool but studies of the back-loop are largely neglected in resilience literature (Folke 2006), including island studies. A primary aim of this research is to identify phases of collapse and reorganisation. “Capital” (Box 1) represents a shorthand for describing “potential” and “connectedness” in social and ecological terms (Abel, Cumming et al. 2006). Abel et al. define the Ω phase as one in which the loss of capital is large enough to require rebuilding of capital through self-organisation or an injection of capital from higher levels, so that the system can reorganise or recover within its regime or shift to another desirable one.

3.3 Data collection

A mixture of data collection methods are recommended for coral reef management studies and (Bunce, Townsley et al. 2000) and social research in Africa (Bulmer and Warwick 1993). Having experimented with stakeholder groups recommended in some resilience methodologies (Walker, Carpenter et al. 2002) it was decided that island realities meant individual interviews gave people more scope to express themselves freely and without risk of sanction. Exploratory semi-structured interviews were completed with a broad range of key stakeholders with direct or indirect influence over policy formation (Abel, Cumming et al. 2006) – including officials and practitioners from government (local and national), NGO, donor, finance, fishing, farming and tourism

sectors. A total of 70 such key stakeholders were interviewed in Rodrigues and Mauritius during fieldwork from November 2005 to November 2006. Interviewees were selected from a broad cross-section of society to give a broad contextual overview of Rodrigues and issues relevant to MPA (interview categories included government, finance, donor, NGO, academic, fishing, farming, livestock, tourism). Interviewees described their memories of the island, how it had changed over time in social and ecological terms, and what could help or limit the island's prospects. Interviews were recorded and translated from French and Creole into nearly 1000 pages of English text to establish decision-makers' perceptions of the causes, extent and timing of key periods of environmental degradation and their social and ecological consequences. Their accounts and the stories surrounding them are referenced extensively to illustrate commonly-held perceptions (see appendices 5 and 6 of particular relevance to this chapter). Timelines (Walker, Carpenter et al. 2002) were used to synthesise, organise and fill gaps in historical information, and to identify key issues, including recurrence, change (decline and recovery) and opportunity for policy intervention. Such qualitative research has the advantage of being emergent (Creswell 2003), just as social-ecological systems are emergent and shaped partly by thoughts and actions of humans. Reference is made to the limited secondary data and literature on Rodrigues, including texts detailing colonial administrative records difficult to access (North-Coombes 1971), government statistics (CSO 2000; CSO 2005), development reports (e.g. KPMG 2006; UNDP 2006), and scientific data starting with a recent marine biodiversity survey (Oliver and Holmes 2004). An attempt was made to fill in recent gaps in little-recorded local history using oral accounts from respected island elders (Gontran 2006). Interviewee side-comments from research in other chapters were also used (Bunce, Rodwell et al. 2007; Bunce, Rodwell et al. 2008). The most complete available rainfall data was processed in the study to identify recent periods of climatic stress.

4. HISTORICAL CONTEXT

Detailed historical perspectives are particularly relevant to long-term social-ecological studies for understanding persistent trends in social-ecological cycles (Walker, Carpenter et al. 2002). The literature attests to a lack of research on distant and recent history with notable exceptions (North-Coombes 1971) covering periods up to the immediate post-independence era (1968). This section synthesises primary and secondary data to provide a timeline of Rodrigues' past and recent history relevant to a consideration of trends from a social-ecological perspective using the Adaptive Cycle.

Rodrigues was first charted (1528) and settled (1602) by Europeans. It has been suggested (Faublee and Urbain-Faublee 1963) that early Arab, Indonesian, or other navigators of the Indian Ocean from Madagascar may have used the island due to abundant screw pine (*Pandanus*) and tortoise. Both were used as a famine food and victual by early seafarers (North-Coombes 1971; Springer 2003). Migrant Huguenot French settlers reported no indigenous people, and therefore no existing belief and taboo systems relating to the environment to challenge the practices of incoming Europeans and a small contingent of African slaves (Gade 1985). Both groups were gradually outnumbered by Africans slaves liberated mainly in Mauritius after abolition laws (1807-1830) established after a power shift in the region from the French to British (1812/15 – population <400). Settlers reported arson forest fires and livestock theft in early slaves protests (Jahangeer-Chojoo 2006). An increasingly homogenous Creole culture under Roman Catholicism and remnant African influence developed, with French cultural and language influences surviving under British rule from the distant colonial seat in Mauritius.

Rodrigues is a marginal island of secondary importance in history. Early island history was determined from afar - by the myths of Europeans (reports of discoveries of Eden

in the region) (Grove 1990; Grove 1995), religious and Napoleonic wars in Europe (European emigration), emerging global trade patterns (Cape route to East India), regional military struggles (British-French naval battles over Mauritius and trade routes) and distant energy/raw material needs (sugar cane exports, U.S. whalers).

Together with an emergent British view of isolated Rodrigues as a “useful appendage to Mauritius”, these led to rapid depletion of abundant tortoise and then turtles for passing ship victuals, with French traders forging early links surviving to this day between Rodrigues and the present regional French/Creole overseas territory of Reunion (Medea 2002). Any further integration was limited by all trade and communication passing through Mauritius (Jahangeer-Chojoo 2006). Unsuitable for the sugar plantations rapidly covering Mauritius, Rodrigues’ secondary importance as a smaller sister island (after its initial strategic value) is suggested by various colonial plans for its use as a leper, quarantine and penal colony – even though none were realised and island labour benefited from being largely free of human communicable disease (North-Coombes 1971).

Settlements initially grew and decline partly as a function of boredom, tortoise depletion and regional naval conflict (French/British). British Crown land tenure rules and taxes then appear to have had a dominant role in shaping the landscape. Dispersed population patterns emerged as freed slaves sought self-sufficiency (Gade 1985), a trend associated high infrastructure costs to this day (KPMG 2006). Land laws were routinely flouted, with African swidden-farming practices, squatting and animal roaming leading to degradation. Amid general lawlessness, autocratic officialdom was noted by 1830 on an island with no democratic rights (North-Coombes 1971; Gade 1985). Extinctions, including a Dodo like bird (Solitaire), and environmental degradation on land were recorded during early settlement (Oliver and Lynch 2004). Clan-like rivalry developed among descendants of early French settlers (North-Coombes 1971). By 1860, when basic public institutions were founded (schools, clergy, tax, courts) leaf

build-up from endemic trees and tree fire marks were noted, suggesting removal of forest cover and rising risks of soil erosion if cover was not restored on steep slopes and farmers settled into gaps on gentler inclines. Whether rats, fires or cutting contributed most to deforestation is unclear but repeated official calls to limit tree felling on slopes to avoid deforestation of the island were ignored in the late 1800s (North-Coombes 1971). Local elites ousted an unpopular magistrate but the island lacked meaningful democratic representation and was at times subject to little more than whims of officials on rapid rotation (North-Coombes 1971). Poor trade terms developed with Mauritius, with local traders setting high credit terms and Mauritian traders monopolising the unreliable shipping lifeline. Officials noted a long-term pattern of indebtedness among the population to coastal traders, well before bank and consumer credit expanded other forms of debt this century (late 1980s). Head fishermen ignored rules and exploited crew, while distrust generally came to characterise the wider Mauritian fishing sector, with Creoles viewed as lower caste (Hollup 2000). Sporadic ship losses at sea hit export-based livelihoods - increasingly based on exports of salted lagoon fish. Whalers paid Rodriguans with rum – popular to this day, with problems (North-Coombes 1971).

Natural hazards contributed to Rodrigues rising external dependence on Mauritius in economic terms. The arrival in Mauritius only of “non-slave” indentured Indian labour (since 1830s) was not repeated in Rodrigues, setting the scene for divergent island ethnic mixes and later ascendant Hindu power by independence (1968) (Brookfield 1957). Although still largely free of severe communicable diseases (Julvez 1998) such as cholera and malaria arriving with Indians in Mauritius, Rodrigues’ suffered devastating combinations of cyclones, droughts and crop pests. By 1867 (pop. 1100) officials already doubted the island’s value as a food supplier to sugar-cane focused Mauritius (North-Coombes 1971). On the contrary, natural hazards gradually entrenched Rodrigues’ dependence on rice imports, which competed with the local

maize of freed Africans, which displaced the wheat of a declining percentage in the population of early European settlers (Dupon 1967; North-Coombes 1971; Gade 1985).

Disturbance in social-ecological systems at times appears to have created potential to do new things (Folke 2006). A first notable window of opportunity (Cocks 2003) for change (1879) opened after a harsh drought, typhoid and near famine (with dumping of excrement in the lagoon). The first visit by a Mauritius governor (1880) involved a rice debt-for-labour swap amid falling tax receipts, and new rules for fisheries (1904) and deforestation, labour, quarantine and stray animals. Indian Ocean sea surface temperatures had been abnormally high in the late 1800s (see JISAO-NOAA trend data in Payet 2006), but impacts on Rodrigues, if any, are unclear. Subsequent events appear to have reduced prospects for an end to degradation and poverty. Severe cyclones claimed ships, and together with insect attacks killed more forest, further reducing storm-adapted endemic forest cover otherwise being cut for fuel and building. The planting of exotic filao pine trees stabilised, but modified, habitats – a trend later extended with repeated introductions of other invasive exotics (eucalyptus), more recently mangroves in bays to stabilise erosion silt (EU 2003).

Political exclusion from Mauritius Legislative Council (1885) marked the first of many denials of island representation up to independence, and island issues were neglected. A profitable line in tobacco exports ended after mainland Mauritian trader pressure for an end to preferential taxes aimed at cutting Rodrigues' rice debt. Declining food security in Mauritius raised the importance of Rodrigues' exports, but sporadic official concerns persisted over unresolved issues of roaming animals (cattle and goats), agriculture, water, food, and trade issues. The island then lost strategic trade value with the end of the main era of sail and the opening of the Suez Canal (1886). After a period without regular transport links, the establishment of steam shipping and the arrival of Chinese and Muslim traders prompted an acceleration of fish exports, and the first notable plan in a series of subsequent proposals for fisheries regulations (1892). The

few coastal fisheries reserves sporadically implemented over the years, starting in 1906 (Port Mathurin), apparently failed due to poor delineation and legal force, disinterest, corruption and repeated enforcement failure (North-Coombes 1971; CSO 2005). Regulations governing the control of fisheries dated from 1892 - with net size limits and fishing bans in certain bays, which were never proclaimed. When read with later regulations in 1894 fishing became illegal in any bay, creek or pass within 3 kms of the coast between dates 16 December and 15 February. There was little enforcement, although the cyclone season from December in any case meant fish could not be exported and so were fished less (North-Coombes 1971). However, cyclones and droughts around the turn of the century had forced men normally only farming into fishing, again raising official concern over the state of the fishery. By 1906 fishing restrictions were established at three northern bays based on the December-February closure of net fishing (North-Coombes 1971), although reference to affected areas as "reserves" has little of the modern meaning of permanent no-take reserves. Plans to protect fish spawning grounds were discussed but not implemented. Fishing gear regulations in force to this day (for example, banning the use of beach-creeper nets) were set in 1906, after fishing in the north of the island had at some point been moved out of necessity to the south to make up catches. North-Coombes quotes official reports (date unclear) stating that it had become necessary at around this time for a man to fish for two months to catch the same number of fish that could have been caught in one day 15 years beforehand. Fishers resorted to fishing with nets across lagoon channels, and drive fishing practices continuing to this day in seine fishing.

Island degradation continued into the early 1900s with rapid population growth and water course pollution by a population unable to meet their rice and grazing fee debts. The downward trend was alleviated briefly by an economic boost from the opening of a British communications cable station (1901) to Australia. In 1904 a promising profitable line in tobacco exports ended under pressure from main island Mauritian traders resenting an effective subsidy. Destructive and illegal fishing continued - with fishers

ignoring regulations (1906) – while on land squatting, land clearance (including water courses), deforestation, erosion (increasingly roadside) and animal roaming led to more official concerns but once again little action. By the time rapid population growth and fisher numbers since 1890 (CSO 2005) had stabilised (1920 Pop. 6,500, full-time fishers est. 500) Rodriguans had renewed their demands for a political franchise (1915) (Jahangeer-Chojoo 2006). This was ignored along with official calls for reforms to end degradation as colonial powers focused on World War I. Clearer livestock regulations did emerge (1914), but reforestation was hit by cyclones, with islanders using trees for building and eating introduced exotic palms in hard times to survive.

Amid fears of island collapse a second notable window of opportunity for change appears to have opened as the population began to expand again (1934 = 8,000). Land terracing was recommended as officials warned ominously of Rodrigues as an “island of limitations” and “a burden to be supported” (1934) - urging emigration (Brookfield 1957) to avoid the community’s “ultimate destruction” due partly to the persistence of poor farming practices (North-Coombes 1971). Between cycles of drought and cyclones Catholic civil society – at the core of modern life on the island - expanded with the construction of a large church of coral block and a liberal approach to birth rates (Brookfield 1957). Native plant decline was noted after 1938, which continued (Strahm 1989) and opened space for invasive species (Kueffer 2004). Anti-erosion relief work projects picked up (Anon 2004) but 30,000 fruit trees had to be cleared due to canker (1937) believed to have arrived with rising shipping links. Mirroring the failure to delimit effective fishery reserves at sea (Chapman and Turner 2004), incomplete efforts were made to solve the lack of clearly-delimited grazing area for cattle (“cattle walk”), perpetuating an open access regime (1936/37) on land as in the sea, where new fishing channels were cut (Gade 1985; Paillat 1999). Efforts to end degradation generally and set coastal fishery regulations appear to have suffered with the approach of the Second World War (Gontran 2006). An ongoing ban on seine net fishing until 1939 coincided with “coral park” fishing, an illegal and ongoing destructive

practice of building walls out of broken coral to channel fish into nets and traps (North-Coombes 1971). A seine closed season (October-March) was introduced in 1939.

Particularly high Indian Ocean sea surface temperature anomalies coincided with the War (see 1855-1992 relative to 1961-1990 mean (Payet 2006)), but, as in the late 1800s their impact on Rodrigues, if any, is unclear. Rising use of corrugated iron and concrete failed to stop long-term deforestation but reduced building vulnerability to storms, at the risk of impacts in the lagoon from sand dredging (Anon 2006) for building material. Major port dredging and backfill added to such risks from the 1960s (de Schutter 1999).

The Second World War itself cut population growth rates (CSO 2005) due partly to enlistment of men, but a post-war population boom (CSO 2005) followed the staged return of soldiers (1945 = 12,000), when Rodrigues was again excluded from Mauritius' Legislative Council. A monopoly lease for seine fishing was cancelled shortly after the war as the population grew and per capita land availability for farming decreased (Gontran 2006). Sever cyclone continue to hit the island (e.g. 1945-1947, 1959) and plans for an agricultural boom failed. Donors (FAO) from the late 1960s onwards concluded that much of the island should never have been cultivated. Overpopulation fears in Mauritius (Brookfield 1957) (inc. Rodrigues) meant emigration became official colonial priority into the 1960s (Pop. 1962 = 18,500) (Brookfield 1957). Fears of marginalisation grew (Gontran 2006) among the newly categorised "General Population" (inc. Rodrigues) of whites and creoles as Mauritius' ethnic balance shifted towards Hindu Indians, adding impetus to emigration and leading to later ethnic riots in 1965 (Houbert 1981; Eriksen 1994; Chazan-Gillig 2003; Eriksen 2004). Rodrigues' own population doubled from since 1945 to 24,000 (1972) as local fears of dependency and subjugation by Hindus were fanned by main-island Mauritius' Creole politicians seeking the backing of increasingly enfranchised Rodriguans.

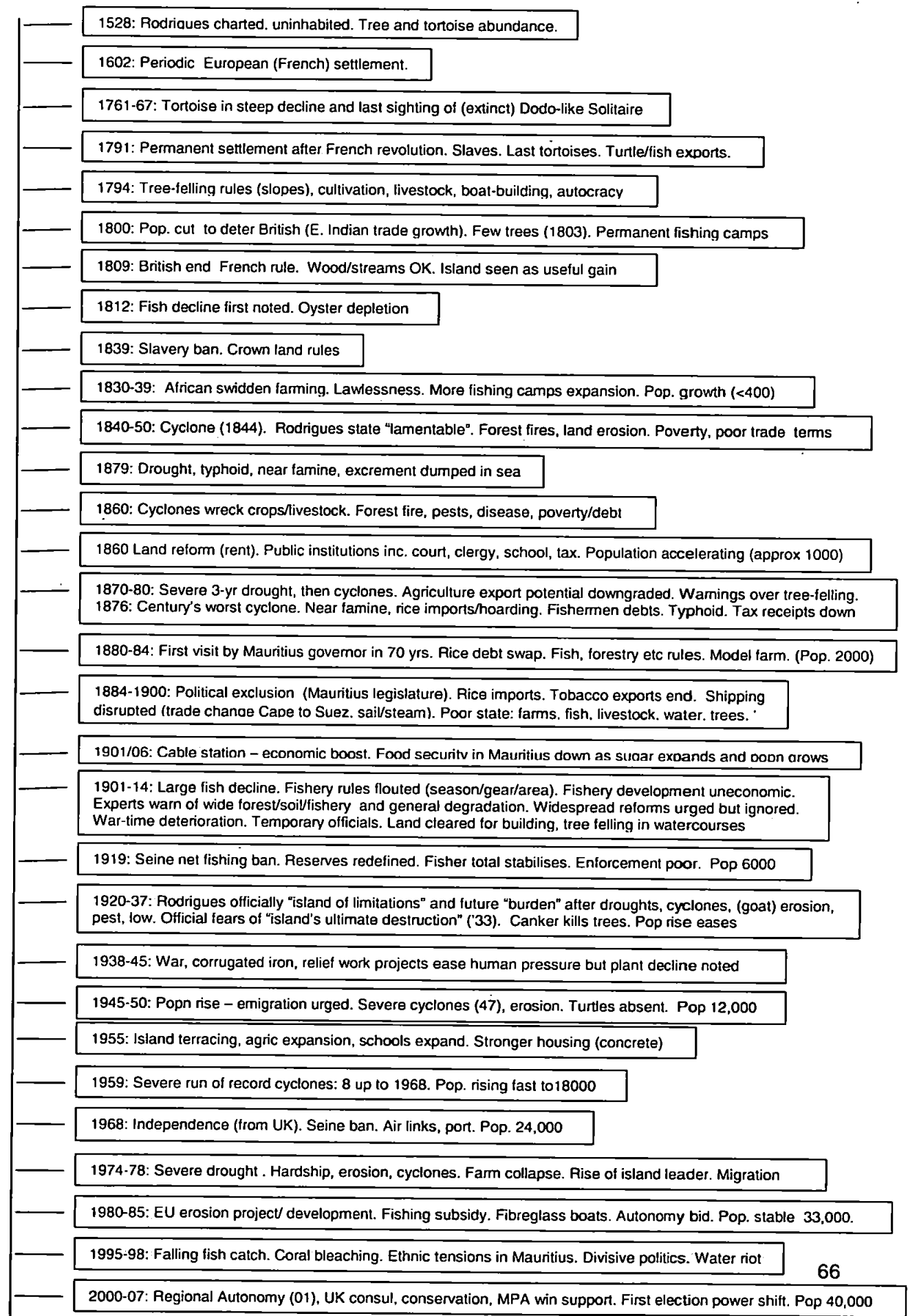
A desire among some Rodriguans to remain part of Britain or France (Gontran 2006) was unrealistic against Britain's wider strategic priority (1968) of retaining the Chagos islands for lease to the U.S. military (Jahangeer-Chojoo 2006). Rodriguans formed their first political party, which gave way to stronger versions in the 1970s. Australia relaxed its White Australia policy sufficiently for mainly Whites and Creoles to leave Mauritius (Neumann 2004). Otherwise, Rodrigues' run-up to Mauritian independence was marred by years of devastating cyclones, culminating in a severely damaging triple-cycle around 1968 (Carmen, Monique, Henriette). Although the island had been bench-terraced (1955-68) with World Food Programme help, regular cyclone devastation complicated an agricultural revolution planned since the 1950s. Crop yields fell and the colonial era ended with post-cyclone food riots, prompting a Royal Navy ship's courtesy deployment from Yemen (1967) to help restore order after mismanagement of emergency food stocks (Gontran 2006). Rodriguans refused to raise the Mauritian flag for a year even as improving shipping and air links knitted Mauritian islands closer together at a time of budget austerity (Gontran 2006). Overall, Mauritius' dependencies during the post-colonial era appear to have related to Mauritius "in a typical colonial pattern: they produced primary goods and bought manufactured goods, just as Mauritius had related to the British Empire. Hence the colonies were doubly colonised and marginalised" (Jahangeer-Chojoo 2006). Mauritius then began the 1970s on an accelerating development path that was to largely exclude Rodrigues.

5. RESULTS

5.1 Relating the Adaptive Cycle to historical social-ecological change

Identification of clear phases of decline and recovery in Rodrigues social-ecological system was problematic due to a lack of data, but also the likelihood that each moved in different phases. Phases proposed (Figure 6) illustrate an attempt to show what may

Figure 6: Timeline with problematic identification of distinct (but here suggested) phases of collapse (red) or recovery (green) in social-ecological systems (re Adaptive Cycle of Gunderson and Holling 2002) due to data gaps or any signs that social/ecological occur in phase.



Chapter 3: Managing Collapse: Resilience and Sustainable Development in Small Islands

represent periods potentially containing episodes of collapse and recovery, some for example in response to crises natural hazards, some to rapid degradation by man, or a combination of both. The key issue here is that policy does not seem to have arrested overall degradation, which overall may be seen as a linear rather than cyclical process. The following discussion focuses on a more recent crisis within living memory for which the constant lack of data for early periods is less of an hinderance to analysis, not least due to the accounts of islanders interviewed in this study who lived through what appears to have been a defining moment in island history. The historical account provides sufficient context for any discussion of surrounding the 1970s crisis.

5.2 Conditions leading to Ω

From the historical context described it appears that Rodrigues had become increasingly vulnerable to human and natural change and less resilient to coping with impacts as independence from the UK (Mauritius including Rodrigues) approached (1968). Returning to earlier definitions of capital used as shorthand by Abel et al (Abel, Cumming et al. 2006) to review resilience in social-ecological systems in Zimbabwe and Australia it seems that by the 1970s:

5.2.1. *Change in five capitals*

Natural capital: There appears to have been a long-standing decline in natural capital in the form of biodiversity (on land and most likely at sea)(Gade 1985; Oliver and Lynch 2004). Cattle-roaming was destroying soil stability. Rising incidences of crop pests and disease were recorded. Deforestation (with removal of cyclone-resistant endemics)(Maunder, Page et al. 2002) and impoverished soil profiles (exposure and nutrient decline) opened the island to the impacts of alternating cyclones and droughts (de Blic 1986; Strahm 1989). Deforestation (Kueffer 2004) may have altered the island's limited micro-climate (Biumaiono, Coro Antich et al. 2005), and impacted the

lagoon. Rodrigues did not have the land area to produce strong daily on-shore/offshore breezes helpful to daily rain cloud formation and burst as in Mauritius. The extent of lagoon degradation is unclear but references to lagoon sedimentation (Rees, Opdyke et al. 2005) from terracing, erosion, port works and fishery fluctuation suggest coastal lagoon depth was falling the end of the 1960s (Pearson 1988; de Schutter 1999). Lagoon health is also likely to have been weakened in places by rising use of lagoon sand and coral for building and/or strengthening the resilience of existing physical capital to cyclones (Cazes-Duvat 2003). Older fishermen also describe cycles of coral growth and die-back.

Social capital: Land tenure rules (social capital) fostered by colonial policy and post-slavery culture (Gade 1985) appear to have exposed Rodrigues' residual natural capital to repeated impacts of natural hazards by the 1970s. Limited and sporadic official policy, and a lack of effective taboo or indigenous belief system (Folke 2004) (human and social capital), meant island governance was poorly-adapted to management of the environment (Folke, Hahn et al. 2005) - which on a wider level is only recent global priority in small islands (Campling 2006). Independence-era mistrust prevailed between different ethnic groups (Eriksen 1994; Miles 1999; Hollup 2000; Srebnik 2000; UN 2001; Neumann 2004) at inter-island level (declining social "bridging" capital). Rodriguans also recall internal division in Rodrigues (declining bonding capital). As one islander commented:

"Imported politics from Mauritius (1967) divided people and created arguments".

Overall, ethnic and religious homogeneity on Rodrigues (Medea 2002; Jahangeer-Chojoo 2006) may have helped the island (Gardella 1982; Eriksen 1995; Des Rosiers 2004) peaceably endure repeated risks of island devastation at the cost of mutual acceptance of open access to resources without harsh sanction.

Human capital: Rodriguan emigration in the run-up to independence started a brain drain and a loss of social memory, expertise and the educated as people left principally for Mauritius, Australia and elsewhere (Neumann 2004) (declining human capital). Memory (personal and institutional) is critical for building resilience along with social networks (Walker, Gunderson et al. 2007). Education developing under Catholic and protestant tutelage remained subject to European values (Moore 1984) and mental modes (Walker, Gunderson et al. 2007). Low school attendance and exam pass rates (UNDP 2003) remained a problem into following decades, perhaps further marginalising Creoles in Mauritian society (Hollup 2000) and contributing to ethnic tension (reduced bonding and bridging capital) seen in riots in Mauritius in 1999 (Bunwaree 2001).

Technological capital: Rodrigues had invested little in technological improvement, relying instead on rain-fed subsistence agriculture and sail-driven pirogue fishing, although there was significant financial and human capital outlay on post-war bench-terracing (World Food Programme). Beyond provision of work (financial capital) and prevention of erosion (retained natural capital), any benefits were limited by falling crop yields (Dupon 1967; Beehary Panray 2004) and declining prospects for official hopes of an agricultural boom to help feed Mauritius' (Jauze 1998) growing resident population and emergent tourism sector.

Physical capital: Rodrigues public service and utility infrastructure was minimal at independence. Poor internal road access, and low water and electricity provision, helped to constrain livelihood diversification options. Internal and inter-island communications remained limited along with external networks generally.

Financial capital: Rodriguans at independence had little financial capital due to a subsistence economy based on rain-fed farming (Gade 1985), a monopoly of credit lending among local traders in the absence of formal farm credit or commercial banks,

and poor export terms of trade and credit leading to hardship among fishers and farmers (North-Coombes 1971). Land lease rules and 90% ownership of land by the state then as now limited options for private land and property sales, or use of them as lifetime and inter-generational credit collateral for funding livelihood choices or investments that could perhaps have limited the impacts of natural hazard impacts. Overall levels of unemployment and wealth remain unknown due to unrecorded economic activities, including inter-island transfers and trading (KPMG 2006).

5.2.2. Summary

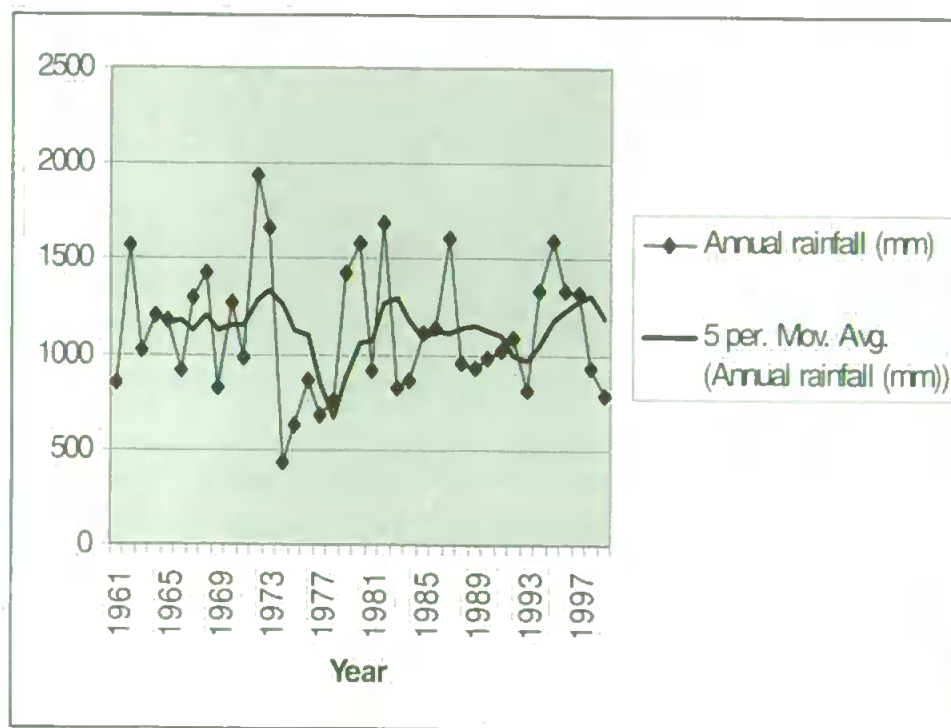
Such a vulnerable social-ecological system may be said to have substantially lost resilience (Folke 2006), in turn implying loss of adaptability (Folke, Hahn et al. 2005). Adaptability in a resilience framework not only relates to adaptive capacity to respond within a social domain, but also to shape ecosystem dynamics and change in an informed manner (Berkes, Colding et al. 2003; Folke 2006). It is possible that such vulnerability had already contributed to earlier phases of collapse and renewal but as it was not possible in this study to explore this possibility in detail due to baseline data gaps it was preferable to rely on the historical perspective presented in this chapter, and in particular perceptions within living memory held by witnesses of proposed collapse and reorganisation (Ω - α).

5.3 Elite perceptions of social and ecological change (Ω phase)

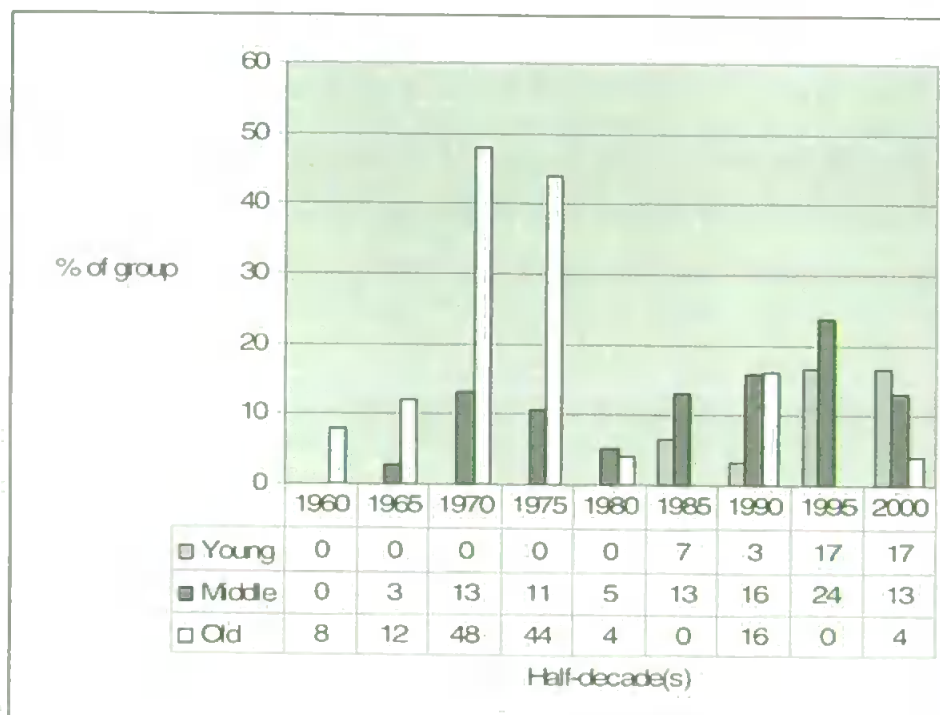
Rodriguan elites' perceptions of subsequent social and ecological change suggest the island underwent a phase of collapse (Ω) or release of capital catalysed by the impacts of a severe five-year drought during a 1970s El Niño Southern Oscillation event (ENSO)(Trenberth 1997). The severity of 1970s drought is suggested by five-year moving average of rain weather data (Figure 7a) from 1961-1997 (data before is patchy) processed as part of this study. Evidence suggests the Pacific-originated

Figure 7: (a) Rodrigues' annual rainfall (Pte Canon) as a 5-yr moving average (left) showing the severity of a long 1970s drought with hard cyclones at each end (Data: Mauritius Meteorological Office) and (b) Three generations of fishers' (n=93: of which Young=18-29 years old, N=30, Middle-aged=30-49 years old N=38 and Old=50-80 years old, N=25) were questioned about period(s) of ecological change: "Has there been a time which radically changed Rodriguan's ability to fish and farm in balance with nature?" and "If so, when?". Year of cited change (x-axis) and % age group citing year (grouped into half decades) show on y-axis. Boxes below x-axis show breakdown of number of respondents by age group (%).

a)



b)



ENSO is linked to Indian Ocean climate (Webster and Yang 1992; Spencer, Teleki et al. 2000; Payet 2006; Pfeiffer 2006). Long-term Indian Ocean-wide sea surface temperature anomalies since 1855 have been notably above the 1961-90 mean (Payet 2006) in successive years only since the 1970s. Unpublished data suggest fishers surveyed in earlier studies regarded the 1970s as the harshest in terms of local impact on their island (Figure 7b). Fishermen not old enough to remember the 1970s referred instead to a later severe ENSO drought in 1997/98.

The resulting social-ecological configuration of island life caused by 1970s drought, with devastating and record cyclones at each end, is described by many islanders in terms of an ongoing undesirable “vicious cycle” – with deforestation, overgrazing, soil erosion, droughts and over-fishing combining to cause drastic falls in agriculture and fish exports ongoing 30 years later. The 1970s drought in Rodrigues coincided with an unprecedented island population rise from 24,000 to around 33,000 within 10 years (from 1972) – an equivalent to the overall rise in the first 340 years of settlement (CSO 2005). Such an increase was considerable on a steep indented island of 204 sq kms with little flat land and only 3.1% of “Good Agricultural”, or 5.7% when including “Average” (FAO 1998). A current population density of 351 sq km is below wider Mauritius’ (+600) but lower urbanisation and traditional farming methods mean land pressure is high. Anti-erosion and farming promotion efforts started in the 1960s were of limited effect in reducing impacts. Fishing effort rose, while enforcement collapsed in the drought, fostering ongoing illegal activity and lagoon degradation (Gontran 2006). Older fishers refer to a rare period of enforcement of fishery rules ending in the 1970s:

“Politics came along in the 1970s, everything broke down and we carried on (fishing) as before”

Crops and livestock died, adding impetus to emigration and a brain drain since the 1960s, while adding to Mauritius’ urbanisation. Coastal water tables were over-pumped during emergency drilling for water during the drought for water in the absence of any

Table 1: Elite perceptions suggesting a severe 1970s drought acted as catalyser of social-ecological change in Rodrigues Island and “collapse” in Holling’s adaptive cycle

Island trader	Nature has changed – that started in the great drought of 1974
Enforcement	In 1974 we had a huge drought due to deforestation -even eucalyptus didn't grow
Ministerial level	When I talk about Rodrigues I talk about a 'Before' and an 'After'. The before is before the 1970s, when Rodrigues produced a lot more (fishing and farming). When the land was much farmed, not so many people working for the government...did not have to struggle to make a living...traditional economy
Livestock official	Before the drought ... "There were cyclones, there were many natural trees – Rodrigues was in a more natural condition ... Fewer people... The rivers flowed all year... (There were) endemic trees ... but we used a lot for wood fuel.
Regional leader	The more they killed the forest the more the exodus to the sea (to fish) was accentuated. Crops were rotten and the cows died. There used to be fishers only on the coast but with the great drought the farmers inland could no longer win (and fishing rose).
Ministerial level	It was catastrophic. People had to walk a lot for water, the crops were abandoned, and the cows had to climb into the hills (beyond agreed limits). They ate everywhere, in the (forest and grass) reserves - they were destroyed.
Regional leader	Farms were abandoned; people were employed en masse in the government. So the lands were left ... lost its fertility ... erosion did the rest of the job. There is not enough water. Lands were cultivated during my grandparents' time. Not now. We used to produce maize.
Island exporter	Before 1974 we exported a lot of livestock to Mauritius... we lost 80% of our cattle in the drought
Enforcement (marine)	There was a (modernisation) boom in the 1970s. We started to build with basalt blocks and we de-rocked (the hills and terraces) to make roads and houses. This and deforestation set off land degradation. The sediment went into the sea, where it was trapped by the reef barrier and churned around the lagoon (hitting fishing).
Ministerial level	Dietary habits changed. We ate what we produced (but) after the drought we stopped, and imported rice came to replace the maize that we ate
Government/ donors	I don't know if it is climate change but we see it everywhere -- we are getting more and more extremes of weather so it floods incredibly
Enforcement	The danger is that we do not slow the degradation of the environment and man's contribution. If not, Rodrigues will not be here in 75 years. Rodrigues will be a bare land. It could certainly happen one day, like on Easter Island. Everyone took the wood to make statues. There was little left so people fought to the death. There is no great mystery about the statues. It is that – simply

collection and distribution network – setting a precedent for mismanagement of a previously untapped central perch aquifer and chronic water supply deficits to the present day. The drought ended with another severe cyclone (Celine) destroying 500 houses, killing 32,000 animals and renewing erosion. Interviewee perceptions highlighting the deep impact of the 1970s drought are shown in (Table 1 and App. 5). Such changes in livelihood catalysed by natural hazard may be seen as a release of capital and a loss of response diversity and resilience (Marschke and Berkes 2006). Rodriguan livelihoods typically include a shifting mix of farming, fishing and livestock rearing, with drought impacts feared more than cyclones:

"After a cyclone we can still have a winter harvest. Plant some vegetables and some onions. Try to shelter the animals and give them grass. But with the drought – nothing. We planted nothing. The animals had no water, no grass, and no pasture – nothing. So the cyclone is preferable to the drought. At least it brings water."

The long-term risks of climate change in Africa generally in terms of agricultural production are well-reviewed (Hulme, Doherty et al. 2000; Sanchez 2000). Severe climate events in Rodrigues appear to create full-time fishers out of farmers and/or fisher-farmers:

"That is why there are so many people in the sea – no jobs and drought"

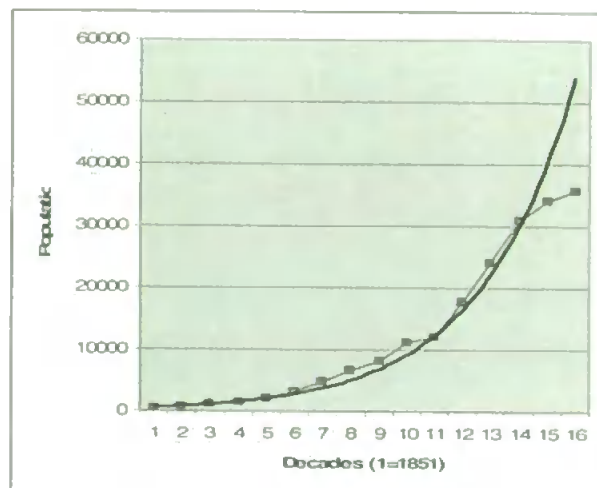
The cyclones of the late 1960s included current records, but an absence of reliable longer-term weather data hampers broader scale comparisons. Severe cycles of crippling cyclones at other times are reported to include 1863-64, 1872-73, 1875-76, 1962-63, with the 1875 cycle (two in four months) believed to have been particularly devastating (North-Coombes 1971). Respondents' comments suggest long gaps between severe cycles of droughts and cyclones may have worked against the development of adaptive responses to stress:

"There were always big ones (cyclones) in the 1940s – 1943, '45, '46, '47 and then in 1947 the cyclones suddenly disappeared. You heard no more of them to the point you forgot about them. Then in 1959 we had a really strong one - and that brought Rodrigues to its knees!"

This raises the possibility that shifting baselines among Rodriguan fishermen (Bunce, Rodwell et al. 2008) applies to current island elites, and prior rotating successions of colonial officials. Such phenomena are regarded as detrimental to adaptive policy-making if not understood (Pauly 1995). Over one century ago (pop. 1,500) officials spoke of Rodrigues in terms indistinguishable from current local perceptions of the 1970s drought and later years - despite an intervening 20-fold population rise:

"There had been a succession of droughts and cyclones which had destroyed all the crops and turned into fishermen a large number of the inhabitants who (normally) were purely farmers ...Larger fish were driven away from waters where in 1890 one could catch by line in a day as much fish that could now be caught in two months" (Rouillard, 1904, quoted in North-Coombes 1971)

Figure 8: Population growth by decade (1851-2000), with a post war stabilisation (decade 10) (dotted line) compared to the trend (solid line). This was followed by renewed exponential growth in the population from 1951 to 1981 (decades 11-13). Population thereafter stabilised compared to the trend following a long and severe 1970s drought. Rising emigration at rates above natural increase was enabled by transport links and economic opportunity in Mauritius and, for those with the means, Europe and Australia.



Population growth rates preceding each of these two periods (1890s, 1970s) were both met with official concern and remain the two highest recorded for Rodrigues (CSO 2005)

5.4 Reorganisation (α) after collapse (Ω)

This section summarises key developments since the 1970s of relevance to Rodrigues' reorganisation. These included policies not necessarily intended as a response to natural hazard but which through their timing had a large and sometimes negative impact beyond providing immediate relief. Such unintended consequences (Walker, Gunderson et al. 2007) appear to have prolonged the period of collapse, with Rodriguans trading short-run gains for long-run cost by degrading the environment. (**Following sections of chapter 4 to be read with closely with quotes in Appendix 5*).

5.4.1. Migration* (e.g. see App. 5)

Decisions taken by Rodriguans themselves to emigrate (Figure 8) were initially prompted partly by political fears of Hindu dominance and rising transport links, rather

than impacts of natural hazards. However, the trend accelerated in the 1970s after the severe 1970s drought, ending exponential population growth rates since the 1850s. Internal and external migration provided a critical buffer (Folke, Carpenter et al. 2002) of resilience for the island's social-ecological system. Should migration flows reverse, for example through ethnic tension in main-island Mauritius, economic downturn in Mauritius or greater livelihood scope in Rodrigues, there could be accelerated pressure on island resources. Outward migration still accounts for perennially high percentages (> 50%) of annual natural increase in the population (CSO 2005). Whilst relieving human pressure this appears to have created a "lock-in" (Read 2004) of economic stagnation and depression worsened by a high birth rate but ageing population as the young leave. In the face of significant external stress, net outward population displacement may be an indicator of breakdown of social resilience (Adger 2000).

*5.4.2. Perverse fishing incentives**

Lagoon degradation in terms of ecosystem services has continued, including rising impacts on fish and coral (Anderson 2005; Hardman 2005; Hardman 2006; Hardman 2006; Hardman 2006). Five existing reserves with bans on seine net fishing were gazetted around Rodrigues in 1986 based on failed inshore reserves set in 1906, but they were never implemented and the general view on the island is that they have never been effectively enforced. Social security payments (Bad Weather Allowance) for fishermen (triggered by wind-speed) were also introduced in the 1980s. These were (and still are) paid on days when sea conditions (judged by wind-speed) in Mauritius are too dangerous but local conditions mean Rodriguans fish and collect subsidies at the same time (Gontran 2006), leading in turn to registrations of more full-time fishers. Numbers rose from under 500 in the 1970s to 2069 registered in 1992, and a current estimate of 5,000 or so with part-timers (Bunce, Rodwell et al. 2007). The creation of a Women's Ministry in Mauritius, promoting UN-backed livelihood schemes for Rodriguan women, and (failed) donor projects created an expanded but chaotic and un-enforced

octopus fishery characterised by over-fishing and destruction of habitat by fishing practices including walking over large tracts of reef with crowbars (Lynch 2005).

"The number of fishers went up considerably when the Bad Weather Allowance was introduced in 1985. It raised the number of women coming from all corners of the island. It is paid from only 19 knots of wind, which is more common here than in Mauritius. Many fishermen will still fish when it is 25 knots, knowing they will still be paid. They fish for the allowance!" (Former Minister for Rodrigues)

Such incentives limit potential for building ecological resilience (Myers 2007; Walker, Gunderson et al. 2007) and add to risks of long-term over-fishing as a cross-scale driver of collapse of coastal ecosystems (Jackson 2001). A shift from wood to fibreglass boatbuilding eased pressure on forests, but coupled with rising bank credit and donor policies extended fishing range, effectiveness and overall effort.

*5.4.3. Collapse of farming, rise of state sector jobs**

Farm workers and others leaving the primary sector for, initially, temporary relief work during the 1970s drought employment, were made pensioned full-time state employees around election time, entrenching a pattern of farm abandonment. Interviewees reported changing expectations of future generations away from agriculture:

"Before the drought people did not want to work for the government. The effect of the drought is that the government hired almost everyone... there was nothing to do. Agriculture suffered...the people who went to work for the government were good farmers."

Agricultural output in 2000 was below 1970 level, with land area cultivated falling from 1571 hectares in 1989 to as low as 173 ha in 2004, although backyard agriculture expanded for local subsistence. Rodrigues may also have been symptomatic of a global fall in agriculture as a primary livelihood as economic, transport and communications systems increased the density of links between rural and urban areas.

Cattle farming collapsed but then accelerated back out of control, with head rising from 3,841 in 1979 to 12,000 by 1999 (KPMG 2006) (before a 50% cut), while required

grazing land shrunk due to competition from other uses. A recent acceleration of goats and other faster-cycle livestock implies continuing impacts in terms of soil erosion, reforestation and competition for potable water.

Farmers left the land and sold terrace stones for infrastructure projects and housing, facilitating erosion. State employees held on to leases of good land (lock-in) in the continuing absence of any coherent land allocation policy. Property rights and land tenure remained poorly-defined and overlapping, hindering cadastral planning and resolution of long-standing open access resource problems (Gade 1985; Buck 1989; Anon. 2006).

*5.4.4. Land tenure and water management**

Farming decline and land planning remained locked into a pattern of open access use and degradation. Land tenure issues were left unaddressed, with unclear and conflicting rights encouraging squatting, animal roaming and unplanned development with poor infrastructure. State ownership of land limited opportunities for raising capital.

A lack of water recharge to the central aquifer supplying 40% of demand is a major island concern. A lack of irrigation in regular droughts has encouraged farmers to fish on a more permanent basis. Water networks were installed since the 1970s but management of water collection and distribution remained poor. Chronic shortages became normal rather than seasonal (FAO 1998), with demand far outstripping supply.

"The terracing was a good idea but the problem was that we lost our water. We cannot plant anything because of the droughts and it is getting worse... There is no work so the sea suffers"
(Old fisher)

Water demand is already believed to be double the 5,827 cu m/day supplied by public infrastructure in low periods of 2000. This makes about 167 litres/day/habitant or 60.7 cu m/hab/yr, far below the World Health Organisation's severe water stress level. Of course, much of the deficit is supplied by 'virtual water' (the water used to grow

imported food) but it illustrates the problem; the island cannot be self sufficient because it could never supply enough water to meet primary human needs, let alone an large expansion of tourism with far higher per capita daily water demand. Desalination plants (2x2000 cu m/day) may be built for emergencies but require large energy inputs. Overall daily demand of around 20,000 cu m/day is projected for 2020, when water stress due to climate change is expected to be acute in Africa. Required investments in impound reservoirs may take until then (KPMG 2006). Livestock, irrigation and human needs compete for daily supply. A local water riot in 1998 highlighted risks of future shortages through failure to invest in infrastructure (Berthelot 2002). One hotel desalinates its water - an expensive capital cost for inward investors raising questions of impacts on the lagoon and the possible extent of economic diversification. In some non-state islands serious declines in the quality and quantity of potable water have emerged as critical environmental health risks, provoking user conflict in tourism development and questions of equity in distribution (Stonich 1998; Pigram 2001).

*5.4.5. Reforestation**

Trees, rather than livestock, are fenced into enclosures as farmers and herders resist change. Deforestation gradually eased after the 1970s but officials recall this being due not to effective policy on wood-cutting but the arrival of liquid fuel imports, new building materials, fibreglass boatbuilding (late 1980s), and, critically, gas and electricity. Thorny acacia planted from 1977 stabilised soils and limited livestock roaming but produced a feedback loop by invading large areas of the island and presenting a new health issue for humans and livestock, and aesthetic issues for tourism. Eucalyptus and other exotics (Kueffer 2004) were planted earlier out of a what one forestry expert on the island described as a misguided attempt to "do something" to correct deforestation by ancestors, while some earlier colonial officials perceived that the island should have more palms to make it more "tropical" (North-Coombes 1971).

Recent reforestation using endemics has been more successful in small areas despite enforcement issues, including cutting for fuel and traditional infusions and medicine.

*5.4.6. Donor projects**

As is common in small islands, responses to the drought and policy programmes afterwards were largely formulated and funded by outsiders from Mauritius and Europe (Baldacchino 2002). There was little local input due partly to significant capacity gaps. Donor-backed projects included a major Anti-Erosion project (1986-2004) to revive productive sectors through land, irrigation, marketing and other initiatives (Anon 2004). Despite policy successes, notably with produce cultivation, agricultural decline continued along with erosion, with associated risks to the lagoon fishery and coral health (Hardman 2004; Fabricius 2005). French-model fishing and farming cooperatives failed. Productive sectors benefited from rising credit, irrigation and concentration of farming in fertile valley bottoms but little attention was given to marketing. Table produce culture added to water demand but enabled supply to local people and tourists.

*5.4.7. Inter-island power shift – rise of regional leader**

An agent of change emerged during the drought. A charismatic ex-Catholic priest given to biblical references and living at the highest point of the island rallied the rising populace (1976), raised Rodrigues' political profile (new Ministry for Rodrigues) and delivered semi-autonomy by 2001 with assistance from political allies in power in Mauritius in the 1980s. However, identity politics and cross-party resentments fostered regularly cool inter-island relations. The tone of debate from Rodrigues was set largely by one authoritarian character prepared to ignore unwritten rules to down-play ethnic and religious difference in Mauritius "Rainbow" multi-ethnic society. Perhaps because politics is comparatively new to Rodrigues, participants report problems in cooperation - an absence of which is referred to by many officials as an obstacle to effective policy-

making and project follow-up. On a general level, the nature of political relationships linking small islands can determine 'to a significant extent' their ability to access migration-remittance and aid/bureaucracy opportunities (Bertram 2004). A trend of multi-insularity – or ethnic communities isolating themselves from contact from one another - in archipelagic small islands breeding island specific nationalisms within the same administrative units is referred to in island literature (Baldacchino 2002).

*5.4.7 Dependence**

By the time efforts were underway to unify and coordinate government, donor and other project initiatives in 2006 Rodrigues was dependent on central government for around 90% of its annual budget (2005), with 67% for wages (2004/2005)(Clair 2005). This left the island vulnerable to external shocks and national austerity measures as global (WTO) and bilateral trade rule (Lomé) changes catalysed a national readjustment towards services (Baldacchino 2002). Rodrigues' actual budget in 2006 (1,163 million rupees) was 5.5% below its proposed needs. Fishers' Bad Weather Allowance benefits were cut in the same year, prompting violent fisher protests during a period of economic inflation linked to an austerity budget. The island's figurehead of 30 years was beaten by a mob of protesting fisherwomen (pers. obs.) and soon afterwards lost elections to the regional assembly's opposition, marking the first notable transfer of democratic power on the island in 400 years.

5.4.8. Tourism

Rodrigues expanded tourism following the 1970s (Bunce, Rodwell et al. 2008) as communications and links to the exterior improved but the sector expanded at a fraction of exponential growth in Mauritius and declined after 2000. Viewed by donors and officials as a local market creation tool for farming and fishing sectors, tourism remained subject to investment risk (hotel closures in slumps), high operating costs, poor skills base, local scepticism, irregular tourist flows and remoteness affecting air

ticket prices (Anon 2001) and outsider control. Necessary infrastructure is basic, while Environmental Impact Assessments in Mauritius generally, including Rodrigues, tend to be too cursory for avoiding the kind of ecological damage seen in Mauritius (Ramessur 2003; Ramjeawon and Beadassy 2004). Plans for tourism are increasingly linked to new Marine Protected Areas (Gell 2005; UNDP 2006) but Rodrigues has no body overseeing coastal management in an integrated manner.

5.5 *Shift in island "state" or configuration*

Overall, respondents' comments (and limited secondary data) suggest that since the 1970s Rodrigues may have shifted into a non-productive pattern in many respects resembling a MIRAB economy - dominated by factors of Migration, overseas Remittances, international Aid, and Bureaucracy to create jobs (Bertram 1999). The MIRAB model developed in island studies originated as an attempt to model the stylised facts of modern economic development in small Pacific islands (Bertram and Watters 1986). The sustainability and development prospects of such islands relies upon the "continuing operation of the stabilising negative feedback loops which kept the aid flowing, the migrants moving, the bureaucrats operating and the remittance networks alive, while the island society and culture (are) reproduced through time and across trans-national space". In MIRAB economies the "bust"-phase of economic cycles is often missing (Kerr 2005), with aid flows often funding the burgeoning bureaucracy. Such economies are generally seen as unsustainable without long-term assistance, not least because aid donors may suffer fatigue and long-run remittances decay.

MIRAB is just one of three proposed taxonomies of small island socioeconomic formations which also include PROFIT (P people considerations; R resource management; O overseas engagement; FI finance, insurance, taxation; and T transportation) and SITE (Small Island Tourist Economies) (Treadgold 1999;

Baldacchino 2006; Bertram 2006). These are not all considered here in full but perhaps islands can shift from one configuration or state to another (McElroy and Morris 2003; Bertram 2006) in a multi-equilibrium system susceptible to feedback loops? Of particular relevance to Rodrigues, it has been suggested that more successful small islands may shift along a continuum from MIRAB economies to Small Island Tourism Economies (SITE) (Treadgold 1999). Such proposals from a resilience perspective resemble alternative social domains, whose dynamics in social-ecological systems are hard to consider in tandem with ecological components (Walker, Gunderson et al. 2007). MIRAB may be a strategic goal of regional island governments but Rodrigues' dependence appears to be viewed as an "undesirable" configuration by the Mauritian government. Rodrigues at times talks of itself as a nation or country without any of the trappings to support such fantasies. Central government favours an economic revival integrated fully within Mauritius – with its rising food import requirement linked to international tourism. However, Rodrigues has lost much of its landscape functions for farming (regulating water, nutrients and organic matter), with equivalent risks emerging in its reef lagoon fishery. Elsewhere in the nearby Indian Ocean, the Comoros islands and (French-dependent) Mayotte island have already been proposed as Indian Ocean MIRABs, with nearby wealthy (Creole) Seychelles a typical SITE (Bertram 2006). Returning to this study's consideration of collapse and reorganisation starting in the 1970s drought, suggested phases of collapse and reorganisation are here presented (Table 2).

It is necessary to consider such development trajectories in depth here because it seems that superimposed on the island's woes is an issue of scale and boundary conditions. Conventional sustainability (social, economic, political, ecological, etc) is obviously unattainable with current population levels and resource availability (e.g. water, food, fuel). The question not answered here is "how far do you need to extend the boundaries to reach a situation where sustainability is possible? Is it to Mauritius or

Table 2: Slow and fast moving variables proposed as contributory to a shift in Rodrigues social-ecological configuration to one resembling a MIRAB economy

1. What caused the collapse?	2. What was the nature of the collapse?
<i>Historical forest /soil degradation</i> <i>Declining per capita land area</i> <i>Limited crop range/poor practices</i> <i>Land lease system (open access)</i> <i>Reliance on rain-fed farming</i> <i>Political uncertainty/ budget limits</i> <i>Poor education, external decisions</i> <i>Poor market prices (maize)</i> <i>Climate variability, events</i> <i>Lack of trust</i>	Water shortage, over-pumping, water table pollution Crop and livestock loss Destruction of forest /grazing reserves and terraces Farm abandonment (food insecurity) Accelerated soil erosion / lagoon sedimentation Damaging pressure on marine resources – with repeated fishery enforcement failure Emigration / Brain drain Gradual social fracture, enhanced mistrust Demand for local political power
3. The nature of recovery	4. Factors affecting recovery process
<i>Population stabilisation</i>	New emigration routes , Creole community in Mauritius, cheap labour demand
<i>Unemployment (dependence on external subsidy)</i>	Farm reform failure, consumer culture, global shift to services (limits options for school failures), competing labour (Asia), dependence habit
<i>Dependence (budget/state jobs)</i>	Rising wealth in Mauritius boost wider economy (Lomé / Cotonou preferential trade with EEC, Mauritius Export Processing Zone), voter appeal (elections)
<i>Shift towards tourism sector (rising natural resource requirement)</i>	Global tourism trends, regional competition (inc. Mauritius), but air access bottleneck (near-monopoly), remoteness
<i>Fishery expansion (lagoon and fishery degradation)</i>	Politicisation, perverse incentives, rising tourism demand, shipping and refrigeration, limited livelihoods, drought impacts, poor credit in past
<i>Livestock overstocking (land/forest degradation, rising water demand)</i>	Continuing open access regime, market demand, donor policy, farmer view of cattle as “wealth store”, taboos about cows in Mauritius (Hindu)
<i>Farming pattern shift to valleys (water-needy table produce)</i>	Donor projects, erosion/poor yields/water shortage on hillside, soil nutrient loss/ salinity, table produce demand, tourism/healthy diet
<i>Food import dependence/ diet change (rice “invasion”, fish)</i>	Drought, underinvestment, youth disinterest , traditional farming, “lock-in” of land, pests/disease, maize production vs. rice import costs, fixed prices
<i>Power shifting to autonomy</i>	Island “difference”, financial burden, unofficial networks (Catholic /cultural), rise of strong leader, identity politics, European/US/Papal visits, ethnic riots
<i>Repeated policy failure</i>	Capacity shortage, externally driven policy, mistrust, enforcement issues
<i>Invasive tree cover</i>	Fuel alternatives/ /building materials, reforestation effort, exotics burn less well
<i>Producer to Consumer culture</i>	World trade (Lomé/WTO), Mauritius GDP, credit, government jobs, transport
<i>Time/space compression</i>	IDD, TV, faster/regular ship/air links, ties to Europe, globalisation

beyond?”. This is one of the biggest planetary challenges; self determination works in boundaries that are incompatible with socio-ecological survival. This inevitably leads to political tension and dissent. The paradigm – as it is proposed here – is an impossible one.

Table 3: Proposed slow-changing variables driving island change, and their possible interactions with faster-moving variables to produce undesirable impacts

Slow-changing variable	Interacting with faster variable	Impact
Local Land tenure (lease) system	Population rise and land pressure Regional food demand - population and tourism Sporadic drought/cyclone severity(Payet 2006) Rising state sector employment after drought	Open access resource degradation (Buck 1989). Farm abandonment and food insecurity Loss of knowledge / migration "Lock-in" of usable land (reduced area) Reduced economic options (tourism)
Local Soil nutrient loss	Crop pests and disease (with natural hazards and rising transport links) (Holling 1994) Livestock increase after 1970s slump	Food import dependence Pollution from rising chemical inputs Soil erosion //damage to lagoon fishery (Fabricius 2005)
Local / inter-island Low Trust	Marginalisation of black Creoles/fishers (Hollup 2000; Laville 2000) Economic decline since drought Arrival of divisive identity politics in Rodrigues Decreasing isolation (transport/communications)	Lack of strategic thinking / initiative Economic dependence / marginalisation Migration / ethnic tension in Mauritius(UN 2001; Eriksen 2004) Regional autonomy Resource degradation
Local / global Climate variability	Aquifer mismanagement and possible pollution Coastal saltwater intrusion Impoverished soils (de Blic 1986) Biodiversity loss(Strahm 1989; Anon. 2005; Bunce, Rodwell et al. 2008) Loss of farming / fishing expertise(Dupon 1967)	Declining food security(Sanchez 2000) Water desalination risks to lagoon(Raventos 2006) Rising disease in biota (Harvell, Mitchell et al. 2002) Extension of land degradation to lagoon Ecosystem decline / invasive spp.(Urban, Cole et al. 2000; Gell 2005) Constrained development / dependence(Munasinghe 2001)
Regional/Global Trade patterns /rules	Low educational attainment(Bunwaree 2001) Improving shipping/ air links Market competition within Indian Ocean region New communicable disease (people)(Julvez 1998; Mauritius 2004)	Limited economy / Import dependence Consumer debt / unaffordable credit(North-Coombes 1971; KPMG 2006) Unpredictable local investment/FDI(Armstrong and Read 2002) Unemployment / Migration to Mauritius Aging population / social breakdown(UNDP 2003)

5.6 Summary and key issues

Although the drought triggered the release or "collapse" phase of the adaptive cycle (Ω), the preconditions for reconfiguration were in place before the 1970s ENSO and surrounding cyclones hit Rodrigues. Slow-changing variables at local to global scale appear to have interacted together, and with fast changing variables, to expose the island to considerable impacts (Table 3) of natural hazards (Walker, Gunderson et al. 2007). This case study suggests Rodrigues was in a late K-Phase of Hollings' Adaptive Cycle (fore-loop) before the 1970s drought, implying a prior loss of resilience. Drought was the trigger for a release of capital within the island system, leading to a new configuration increasingly unacceptable (to varying degrees) both to Rodrigues and Mauritius. Rodrigues appears to have entered the 1970s release phase with limited

social, human and natural capital, and low levels of physical and financial capital. Although the latter two rose significantly in the back-loop reorganisation phase (α) natural capital degradation appears to have continued, extending outward into the lagoon despite attempts on land to restore lost capital.

A few underlying slow variables may have been critical to this process through their interactions with faster variables (Table 3 above) – a proposal referred to as the “rule of hand” (Walker, Gunderson et al. 2007). The release phase Ω appears to have involved a further loss of capital on most counts.

5.6.1. Missed opportunities

In describing Rodrigues' historical context this chapter identifies two possible windows of opportunity following natural hazards for reversing a trend of degradation on the island. The 1970s drought perhaps presented a third. Given the recognition of Rodrigues' plight at the time and impacts of belated policy since then, autonomy may represent a fourth window opening since the last ENSO in 1998. Overall, Rodriguans appear to have traded short-term gains for long-term cost by degrading the environment. Such decrease in island resilience means smaller external events can cause catastrophes. Migration and unimpeded movement of people and goods between the two islands for now remain critical population buffers in Rodrigues' current social-ecological configuration, while inward migration remains typically marginal, limiting inflows of new human capital.

5.6.2. Scale and capital flows

During release and reorganisation a system may be at its most vulnerable to change (Walker, Gunderson et al. 2007), because linkages between the system of interest (Rodrigues) and systems at other scales (Mauritius, regional, global) become more pronounced. Connectivity (flows of people, goods, information, money) and connection across scales (Rodrigues and Mauritius) appear to remain critical components of social

Chapter 3: Managing Collapse: Resilience and Sustainable Development in Small Islands and ecological resilience in Rodrigues (Bertram 2006; Janssen, Bodin et al. 2006). Migration (Locke, Adger et al. 2000) opened up new livelihoods in Mauritius, helping Rodriguans cope with the 1970s crisis. Policies introduced in what is considered here to be the (perhaps ongoing) α -phase (back-loop) of Holling's adaptive cycle fostered further environmental damage. Excessive subsidisation may have reduced the ability to self-organise, thereby reducing long-term resilience and raising risks of subsequent collapse (Abel, Cumming et al. 2006). This in turn may have created conditions for a further collapse even while impacts of the last continue to be felt.

5.6.3. Trust

Rodrigues appears to have lacked adaptive governance (Folke, Hahn et al. 2005; Lebel, Anderies et al. 2006) over much of its history (for example - polycentric and multilayered institutions; accountable authorities; integration, participation (Stringer 2006) and trust. A lack of trust stands out strongly as residual obstacles to building social-ecological resilience (Tompkins and Adger 2002). Rodrigues suffers from low levels of trust, participation and integration at local compared to national levels, reducing the effectiveness of otherwise increasingly layered and representative institutions. Institutional change only recently accelerated but religious and cultural modes at variance in Mauritius were formed over centuries. Cultural conservatism may be slow controlling variable reflected in the kind of strong leadership emerging in Rodrigues during the collapse (Ω) phase itself (mid-1970s). This raised potential for adaptive governance but through its duration and nature may also have fostered rigidity and inflexibility, leading to its own collapse in 2006. Levels of trust and governance relate importantly to what "resilience" means in terms "of what, to what" and – critically here – "for whom?" (Lebel, Anderies et al. 2006)

5.6.4. Inter-island issues

This chapter highlighted the criticality of inter-island relationships and proposed the MIRAB-PROFIT-SITE taxonomy of islands in terms akin to resilience, with

governments able to reinforce system characteristics or trigger a switch to another mode of articulation within the global system. External forces dictate the set of forces open in the short and long run, but islanders and their institutions choose the actual trajectory (Bertram 2006). The question is which “islanders” - Rodriguans or Mauritians – which again relates to “resilience of what, to what and for whom?”. Such critical issues relevant more specifically to collapse (Ω) and inter-island relations are proposed from a social anthropological perspective (Diamond 2005). Diamond’s five-point framework of factors possibly contributing to the historical collapse of societies appears to be highly relevant in the case of Rodrigues: damage people do inadvertently to their environment; climate change; the hostility (or friendly support) of neighbours; and society’s response to its problems – environmental or otherwise. Just as in ancient societies such as Easter Island, migration – then by boat and now by boat and plane – is a critical issue of access and escape relevant to adaptive response to crises, regardless of whether “neighbours” are part of the same state. Mauritius constitutes a sole lifeline to the outside world, which in terms of resilience carries risks at island level (though not perhaps at state level). Inter-island issues are explored in island literature (Baldacchino 2006; Bertram 2006) – for example, in terms of “elite” power (Srebrnik 2004), economic growth (Armstrong and Read 2002) and convergence with patrons (Bertram 2004), regional island growth and globalisation (Read 2004) and island political economy (Campling 2006).

5.6.5. External stress

Cross-scale global stressors expected to rise in frequency and intensity remain largely beyond island-level control (Young, Berkhout et al. 2006) - for example, the Western Indian Ocean had a mixed exposure to and impacts from coral bleaching events notably peaking in 1998 (El Niño reversal)(McClanahan, Ateweberhan et al. 2007). Human health impacts (Julvez 1998; Few 2007) during a mosquito-vectored Dengue fever (Chikungunya) epidemic in the SW Indian Ocean in 2005/6 rapidly had severe temporary impacts on regional tourism. Water for agriculture (rain-fed or irrigation)

across global scales is threatened by climatic variability and extreme events linked to climatic change (Hughes, Baird et al. 2003; Cherian 2007), meaning income and survival depend on greater livelihood resilience. The potential for natural hazards to open windows for change is recognised at senior government levels, although not perhaps in ways that necessarily lead to resilience:

(Power) Yeah, nation-building. I think it could be a common enemy or a very big cyclone...it would be a good thing to have a major calamity ...something really strong, to get people to set aside their differences (Mauritian mainland government official)

5.6.6. Back to the future?

Looking to the future (the next fore-loop r and K in the adaptive cycle), elite perceptions, fishers' comments and limited secondary data suggest that from a vulnerability perspective alone Rodrigues' intrinsic exposure to risk as a region is presently similar to those of many SIDS (UN 1994; UN 2005), and with respect to perceived climate change possesses many vulnerabilities proposed more specifically for fragile atolls. Vulnerability and resilience are increasingly seen as directly related issues of sustainability. Rankings of Mauritius' vulnerability in global tables, although relevant, can perhaps only be considered as the loosest of guides to Rodrigues as they differ largely in social, economic and ecological terms.

5.7 Study limitations

As in earlier resilience studies including an African perspective (Abel, Cumming et al. 2006) it is acknowledged here that the historical nature of such studies and an absence of reliable cross-scale and temporal data means explanations are based on judgements and intuition, and the coherence of stories. This study condensed almost 1000 pages of interview transcripts in search of representative local perceptions and it quotes elite respondents extensively. Their temporary and shifting roles often did not reflect their real knowledge and expertise which was often split across different sectors. This complicated categorisation of outputs. It is accepted here that this approach to

some extent limits conventional disproof of hypothesis. Other explanations are possible (Abel, Cumming et al. 2006). Quantitative and modelling approaches would complement this exploratory case study of an under-researched and data-poor site.

6. DISCUSSION

This chapter set out to provide a case study relating to a research gap on how society reorganises following a crisis (Abel, Cumming et al. 2006). Holling's adaptive cycle was used as an analytical tool to explore possible phases of collapse and reorganisation (Folke 2006). Applying this to the case study site, it seemed the island of Rodrigues underwent a societal shift (collapse) out of a productive traditional farming system to one of a dependent consumer society, catalysed by an environmental shock (drought) identified in the 1970s (Walker 2004). However, apparent collapse at local level during the 1970s drought appears to have extended beyond the 1970s, whilst faltering reorganisation starting during the drought still appears to be in progress. This raises risks of the social-ecological system stagnating in an incomplete reorganisation phase with dangers of untaken decisions and unresolved impacts being compounded together over time and scales. The lack of clear delineation in practice between phases shown as distinct in Holling's Adaptive Cycle (Holling and Gunderson 2002) raises several important questions over its usefulness. Is it possible that reorganisation and collapse may run in parallel, with either advancing, receding or petering out without necessarily following the four-sequences in order as Holling suggests? Alternatively, could repeated and alternating failures in each be a downward staircase of declining capitals without any compensating growth and conservation phases? The case study island showed ongoing signs of collapse and incomplete reorganisation in terms of destroyed livelihood, new sources of food and income, migration, and climate change coinciding with new and fractious power relations with the capital island of Mauritius and its modernising economy. It may be that reorganisation simply occurs over far longer timescales than expected, or may involve nested Panarchies during its progress.

Holling's conceptual model as an analytical tool in this study appears to be qualified also by the issue of where to set spatial and temporal boundaries to a social-ecological system. For example, net production from one system might be transferred to another, without which a smaller system, such as an island which has outstripped its capacity to produce, may not survive. Wider issues of whether sustainability is achievable in degraded small islands with almost no resources and a high population are not fully addressed in this study but significant downside risks are highlighted in this chapter. Does the Adaptive Cycle appear to be losing some of its descriptive power as global modernisation processes redefines temporal and spatial scales or is it an even more onerous parable of regional and global unsustainability as Diamond (2005) suggests? Collapse at successively higher scales ultimately leads to fragility at the highest (global) scale, exemplified by current lifestyles that are maintained by fossil fuel energy subsidies from the past.

In terms of reorganisation, earlier studies suggest social-ecological resilience may depend on recognising several constraints on governments to act. These include fostering capacity for self-organisation; avoiding excessive subsidies likely to create exploitative or parasitic relations; and investing or disinvesting in capitals to enable emergence of desired regimes/state (Abel, Cumming et al. 2006). However, barriers to building social-ecological resilience may be considerable. Some are illustrated in this chapter, including negative mental modes, culture and leadership, trust components of adaptability and negative determinants of transformability (subsidies, networking across scales, and low reserves of capital). In terms of barriers to building resilience in an SES it is proposed here that local political systems may be acting as slow variables by comparison with new political structures, movements or ideas generating on a faster cycle but perhaps on a different scale with different timescales and perspective. These could be extended to include the realpolitik of global trade that has rapid dynamics determined by distant markets responding to factors entirely outside

Chapter 3: Managing Collapse: Resilience and Sustainable Development in Small Islands

the SES studied (e.g. the US housing market). In between the two cycles, decision-making and coordination across scales may fail simply due to being - in common parlance - "on a different wavelength". For example, local politicians may pursue short-term agendas or ill-conceived nationalisms to sink an international policy from which it could have benefited. In Rodrigues, there is a residual risk of politicians with little budget and a capacity willingly not responding to crises or pretending to be immune ('ostrich like' behaviour) in order to win populist favour from less educated or informed voters. South African responses to AIDS are a case in point. Does the reorganisation phase need to be considered on a different scale due to globalisation if the outcome it is to be different from the original condition? This may be the only practical way to achieve adaptive behaviour. Ignoring fast developing variables may result in a sudden loss of political credibility at lower scales as an increasingly educated local scale populace sees the reality of what is happening and rebels.

Box 2: Summary of Down's 5-stage Issue-Attention cycle

1. <i>Pre-problem</i>	Knowledge of the problem exists but nobody does anything about it
2. <i>Alarmed discovery</i>	A dramatic event triggers public demand for action
3. <i>Counting the cost of progress</i>	Public and politicians become aware of the costs and trade-offs needed if the problem is to be tackled properly
4. <i>Gradual decline of stakeholder interest</i>	Immediacy of the problem is lost; people have second thoughts; other problems rear up to set new agendas
5. <i>Post problem</i>	Public interest wanes but – sometimes- institutions, policies and programmes remain in place

This case study illustrates the 'regime shift' situation described by Holling and others. In the past reorganisation may have been effective after disturbance of Rodrigues social-ecological system. With autonomy, and new leadership, the current situation remains as unclear long after the 1970s drought. Beyond whatever visions of the future may be preferred in Rodrigues, Mauritius central government has a clear capacity to manipulate Rodriguan politics to varying degrees. Fear of Mauritius is a powerful political tool in Rodrigues, which also has a victim culture underlying its dependency.

The Adaptive Cycle may be particularly useful over longer temporal scales but other analogues exist which provide additionally useful insights for the shorter timescales. In particular, reference is made here to Downs' five-stage Issue-Attention Cycle (Downs 1972). Although criticised for its pessimistic view of the world it would appear to hold useful insights on a general level for developed or developing country contexts. Unlike Holling's cycle, Downs' cycle reflects a rising and falling of response that may not result in long-term reorganisation. It is not suggested here that all social problems go through this cycle either. Elements would appear to have ample capacity to contribute to collapse or stall a reorganisation (or vice-versa).

In Rodrigues, cycles of official concern over island degradation led to no effective action over centuries (Stage 1). Drought in the post-independence 1970s triggered official as well as local demand for action (Stage 2) but wider Mauritius had limited financial resources and other post-independence priorities. Policy responses eased immediate livelihood hardships while some donor policies (with otherwise poor uptake) helped reduce impacts of detrimental human activities on land. Public concerns eased, but in the absence of effective long-term accounting of cross-sector costs and trade-offs (Stage 3) (Brown, Adger et al. 2001) unsustainable resource use, partly due to new policy, continued up to more recent concern over fishery decline in the late 1990s. Autonomy (2001) dominated political debate in subsequent years (Stage 4) but with this in place, and dependency reduction a central government goal public concerns remain high. The island's first change of internal power in 2006 marked the first meaningful alternation of regional power since autonomy but for now the significance of this is limited by the island's lack of a notable economy and limited (and unclear) decision-making powers. The reduction of fishers' subsidies in 2006 provided scope for breaking resilient patterns of dependence by encouraging a shift to sustainable livelihoods but the island's final trajectory remained unclear in 2006. Marine and Coastal Protected Areas raised public interest but prospects for success remain

qualified by income concerns and conflicting priorities among numerous overlapping government, donor and NGO initiatives.

Another option to foster adaptive responses is to adopt policies or practices that limit one of the variables in I=PAT (Ehrlich and Holdren 1971; Schulze 2002). The equation refers to the impact of human population on the environment, which can be thought of as the product of the population's size (P), its affluence (A) and the environmental damage inflicted by the technologies used to supply each unit of consumption (T). Other variants recognise the importance of lifestyles (I=PLAT) and behaviour (I=IBLAT). I=PAT and resilience thinking are usefully close in recognising social-ecological interactions in an era of globalisation (Fischer-Kowalski and Amann 2001). In terms of population the question is what level of population would need to be reduced (here through migration) for the SES to be considered sustainable in terms of key resources such as water supply being maintained intact over the long term? Could this be substituted by a reduction of the impact of technology by decoupling it from an environmental impact? In the case of Rodrigues this seems unlikely as scope for low impact technological development of its agriculture is limited due to a high external energy dependence and severe water shortage. Similarly, an overall reduction in affluence would be deemed morally unacceptable.

The underlying question of whether social and ecological resilience are even related in developing country contexts provides additional problems for setting policy goals (Adger 2000), for example (from a resilience perspective) for rural livelihoods options (Marschke and Berkes 2006); coastal communities (Adger 2000; Adger, Hughes et al. 2005) global pressures (Armitage and Johnson 2006); food security (Fraser 2005); property rights (Hannah, Folke et al. 1996); land degradation (Redman and Kinzig 2003); migration (Locke, Adger et al. 2000) and interplay between periods of gradual and rapid change (Berkes, Colding et al. 2003). Potential for Malthusian scenarios have been avoided in Rodrigues by migration, but is sustainable development even

possible in such a stressed SES when taking into account taking into account cross-scale impacts of goods and services requirements for its maintenance of configuration?

Human society may adapt to crises on a social level but this may still be at the expense of an ecosystems' ability to sustain the adaptation, with traps and breakpoints in the social ecological system appearing in subsequent years, or cascading effects between variables with unforeseen impacts on social-ecological systems (Kinzig, Ryan et al. 2006). Many such problems appear to have arisen in Rodrigues since the 1970s, with scale issues arising time and time again as a critical factor. For example, Rodrigues is still seen as a potential export economy (fishing and farming) for supplying higher scales (national food, international tourists) based on a limited resource base (particularly water) - with combinations of policies combining to reduce vulnerability to climate change. Even well-intentioned attempts to manage resilience may quite unintentionally produce dangerous outcomes that add to stress impacts (Walker, Gunderson et al. 2007).

The semi-autonomous region would appear to remain vulnerable in terms we portray for Small Island Developing States (Pelling and Uitto 2001) but also, we suggest, in terms of drivers proposed in many wider contexts (island and non-island) as possibly contributory to societal collapse. For example:

- (Cocks 2003): population growth, trade, technological change, resource degradation, catastrophe, competition and cooperation within and between societies, war (up to now indirect from higher scales)
- (Diamond 2005) a five-point framework including damage people do inadvertently to their environment; climate change; the hostility (or friendly support) of neighbours; and societies response to its problems – environmental or otherwise.

Diamond's emphasis on neighbourly relations seems particularly relevant to multi-island states – particularly where division emerges between them for any reason, not least ethnic and religious.

Findings presented here underline the importance of adaptive governance and effective social networks (Janssen, Bodin et al. 2006), even though barriers to building social-ecological resilience appear to persist and in some cases may be insurmountable. More case studies are needed and those focussing on under-researched African (and similar) islands would be useful for comparison. Given current limitations in data availability, particularly on social indicators, this study relied heavily on representative narratives. Despite limitations in this study to quantifying the cross-scale complexity of adaptive cycles and possible inconsistencies (Holling and Gunderson 2002; Vincent 2007), it is suggested here with confidence that results demonstrate the complexity of SES that requires the pragmatic approach of adaptive management in order to overcome inevitable uncertainties about system behaviour. Adaptive management can only be employed effectively if the society in question shares a viable long-term vision toward which pragmatic steps may be taken and carefully monitored. Many questions relevant to building social-ecological resilience in such island's with close land-sea interactions await research (Walker, Gunderson et al. 2007). Interdisciplinary approaches may be useful in considering social-ecological resilience in such contexts (Janssen, Schoon et al. 2006). For example, useful insights may be gained from wider island literature, social anthropology and population studies (Diamond 2005) (Cocks 2003). Recent concepts for bridging the gaps between research disciplines not used in this study may facilitate the task (Füssel 2006). Previous studies of Rodrigues from a "Tragedy of the Commons" perspective (Gade 1985) could certainly have benefited from resilience and interdisciplinary perspectives. Of interest to future researchers is the potential relevance to adaptive governance of the growing field of Positive Psychology and its three central concerns: positive

emotions, positive individual traits and positive institutions (Peterson 2006). The field reflects a “can-do” approach potentially offering new and perhaps helpful perspectives on understanding contentment with the past, happiness in the present, and hope for the future.

7. CONCLUSIONS

This contextual case study set out to address an understudied question of the capacity of social-ecological systems to renew, re-organise and develop in a sustainable fashion in response to change or crises (Folke 2006). It used the example of a small island, on which there is a general lack of long-term research on impacts of natural hazards. Natural hazards appear to be catalysers of change in many small islands already stressed by other social and ecological factors and their impacts could be better managed when based on resilience approaches (Meheux 2006; Cherian 2007; UNISDR 2007). The adaptive cycle (Holling and Gunderson 2002) proved useful as a conceptual tool in identifying what are proposed here as phases of collapse and faltering re-organisation but its usefulness in describing short timescale cycles may be limited. For this reason, it appears reasonable to support the notion that the adaptive cycle should not be considered as a metaphor for all system dynamics (Walker, Gunderson et al. 2007). In terms of sustainable development, considerable constraints appear to have arisen in Rodrigues’ recent history making any rapid and easy “win-win” conservation-development strategy unlikely in the short term.

CHAPTER 4

Two principal issues raised in chapter 3 are further explored in the next two chapters – uncertainty over the extent and nature of ecological decline, and livelihood issues at the root of local ability to reduce fishing effort without perpetuating degradation in another ways or across scales (5). Both relate to building social ecological resilience and may help with MPA planning, and acceptance among local communities.

This chapter presents findings from an exploration of fisher's ecological knowledge of a fishery and wider island-level environmental degradation, indicating possible causes of degradation relevant to policy-making. Local knowledge is a form of social memory at the root of social ecological resilience. This is discussed for in terms of its value in data-poor MPA planning contexts and for its relevance to sustainable development.

CHAPTER 4

SHIFTING BASELINES IN FISHERS' PERCEPTIONS OF ISLAND REEF FISHERY DEGRADATION

Keywords – Africa, historical ecology, social-ecological systems, MPA, sustainable development

1. Abstract

This chapter presents the first quantified evidence of shifting environmental baselines from an island-level coral reef fishery (Rodrigues). To survey the extent to which fishers perceive Rodrigues' fishery to be in decline 93 respondents from the three generations of active male fishers (18-29 years old, N=30, 30-49 years old, N=38 and 50-80 years old, N=25) were selected at random near landing stations representative of fishers and fishing methods around the island. Fishers identified from published fish guides any commercial species they believed to have been depleted during their lifetime (Saenz-Arroyo 2005). They also gave dates for the onset of each species' decline, and up to five reasons each for decline and how to stop it. Depletion of commercial fish species appeared to be spreading out from the coast, with a large majority (80%) of all ages of fishers seeing the lagoon fishery as already depleted and unable to meet local demand for fish. Youngsters shared few of their elders' memories of former abundance. Of three generations, the oldest reported more fish species as depleted ($p < 0.001$), including predators indicative of ecosystem health and of interest to fishers, and also marine tourists potentially paying fees to see them. The median number of species reported by the oldest group of fishers was 18, compared to 14.5 for the middle-aged and 8.5 for the youngest. The average number of years of decline cited per fish rose by around 5 years for each generation of fishers (Young=5 years, Middle Aged= 9, Old=15). For many individual species, especially grouper, older fishers stated far higher numbers of years of decline. In particular, older fishers recalled larger catches of the most-cited species, the grouper *Epinephelus multinotatus*, and bigger fish ($p < 0.001$). Based on their own perceptions, older fishers' were more likely to have caught larger fish and landed more of them on their best day ($p < 0.005$ in both cases). Fishers cited a long-standing lack of work and fishery enforcement as the principle reasons for over-fishing and lagoon decline. Overall, older fishers remembered the ecosystem as being in better condition. They gave qualitative accounts of land-sea decline over decades supported this, but generations again differed again their perceptions of change, for example climate, deforestation, soil erosion and coral loss. Most saw reserves with fishing bans as necessary (87%), even though poorly-defined and implemented coastal reserves in the past had failed (88%). Shifting baseline studies may inform the planning of policy of Marine Protected Areas (MPA) underway in Rodrigues and beyond in other data-poor countries prioritising sustainable development. Results presented here support findings from earlier shifting baseline studies in Mexico, but more studies are needed in different ecosystems and contexts to establish global trends and local needs for policy regulation, education and encouraging the better transfer of social memory down through generations.

2. INTRODUCTION

The primary role of long-term over-fishing in the collapse of coastal ecosystems is recognised ahead of all other pervasive human disturbance (Jackson 2001), in particular the overexploitation of large predatory fishes (Myers 2007). The phenomenon of "shifting environmental baselines" (Pauly 1995) may be a contributory factor as it suggests successive generations of fishers adjust to increasing scarcity of fish and fail to understand the extent to which humans have modified their environment over the long term. Fishers, no less than fisheries scientists, may in the process perceive as "natural" the way the environment appeared to them when they were young and then use that as a yardstick for measuring subsequent change. In so doing, they discount the experience of previous generations, running the risk of wrongly perceiving social and ecological systems as stable and pristine and then failing to adapt even when change does occur. For example, the management of reef fisheries: "... (if) it exists, has almost always been instigated long after exploitation has peaked ... Typically the stocks continue to decline even further and over time management targets slip lower and lower" (Bellwood, Hughes et al. 2004). Even if fisheries managers do identify impairment of the marine ecosystem, shifting baselines among fishers may foster resistance to corrective policy, such as marine reserves (Bohnsack 2003). Fishers simply may not perceive any need to change their ways. Fishers' perceptions of environmental state need to be fully understood in coral reef fishery management contexts. Depletion of fish and degradation of coral exposes reef systems worldwide to the risk of unexpected phase shifts to less desirable states (Scheffer, Carpenter et al. 2003). Such change can devastate or limit social and economic development options in developing nations, entrenching their reliance on marine resources for survival. Small oceanic islands with few livelihood options (Armstrong 2003) rely heavily on mixed reef fisheries. Bio-geographical isolation, lower biodiversity and higher endemism (Cronk 1997; Rees, Opdyke et al. 2005) mean such islands can be especially less resilient to catastrophic ecological change (Holling, Carpenter et al. 2004), with a consequent risk

Chapter 4: Shifting Baselines in Fishers' Perceptions of Island Reef Fishery Degradation of societal collapse (Janssen and Scheffer 2004; Hughes, Bellwood et al. 2005; Shertzer 2007).

2.1 Aims and objectives

Evidence for shifting baselines (Pauly 1995) has not been tested in quantitative terms except among fishers in Mexico's Gulf of California (Saenz-Arroyo 2005). No such studies have been conducted in mixed coral reef fisheries or in island contexts. Fishers' insights could inform policy decisions in data-poor contexts but policy-making in reef management often excludes or discount fishers' perceptions (Johannes 1998; Folke 2004) and MPA failure rates are high in developing nations where they are most used (Dharmaratne, Yee Sang et al. 2000; Jameson, Tupper et al. 2002).

This chapter addresses the following two questions:

- Do quantified shifting baselines studies in a mixed coral reef fishery provide useful information on commercial fish species depletion within fishers' living memory?
- Do quantified studies of shifting baselines present among fishers' provide clues to meeting sustainable development goals based on MPA in such contexts?

2.2 Research site

Shifting baselines in this chapter is tested in traditional African fishery based on an oceanic coral reef system surrounding a degraded small island lacking scientific baseline data to help it meet sustainable development goals based on fisheries and tourism. The small island of Rodrigues (18.3 km long by 6.5 km wide) lies at 19°4'S, 63°25'E in the inter-tropical zone of the south-western Indian Ocean 600 kms east of Mauritius. The island's (104 sq km) steep volcanic flanks rise to almost 400m (McDougall, Upton et al. 1965) from the Indian Ocean's largest reef lagoon, whose area is at least twice that of the island and ringed by a little explored shelf of 950 sq kms (to 200m isobath) with two fishing banks - Hawkins Bank and East Bank.

Rodrigues is one of many South Mascarene Islands which together rank highly in terms of existence and threats to marine endemism (Kelleher, Bleakley et al. 1995; Hardman 2006). Over 100 Mauritian coastal and marine species feature in CITES appendices as threatened or endangered. Many others may remain to be discovered. In Rodrigues, 498 coastal species were reported in a recent update of the fish checklist for Rodrigues (Heemstra, Heemstra et al. 2004) but there could be 600, and 1000 species overall when including pelagic and deepwater fish. Rodrigues' corals have been referred to as the most pristine in the western Indian Ocean (Fenner, Clark et al. 2004). The region's corals are a key part of the global carbon cycle but they face rising natural and human pressure (Rees, Opdyke et al. 2005; Payet 2006).

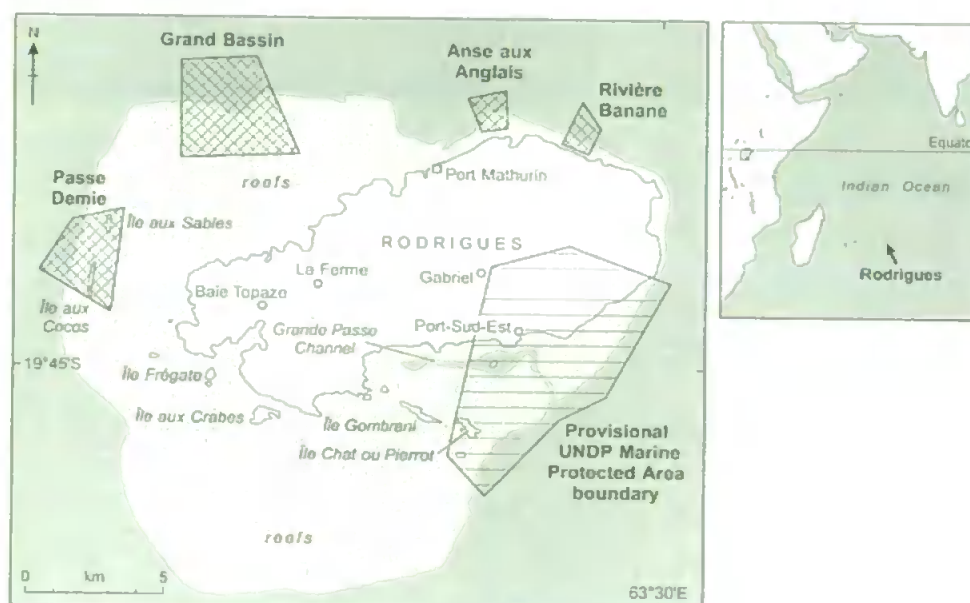
The historical degradation of Rodrigues is unclear (North-Coombes 1971; Oliver P.G. 2004). Early accounts of isolated Rodrigues refer to an abundance of fish in Rodrigues' large but shallow lagoon. Official records (North-Coombes 1971) show fishing probably started in 1792, followed by rapid deforestation and land clearance for agriculture and livestock. Tortoises were rapidly removed for ship victuals. The rapid extinction of Rodrigues' endemic flightless bird, the Solitaire (*Pezophaps solitaria*) is perhaps as emblematic of man's impact after permanent settlement in the early 1800s as the Dodo's demise in Mauritius. There is a general view that land degradation was closely linked to marine degradation: "Human impacts may not have been so outwardly visible on the marine environment (as on land) but have surely been severe" (Oliver and Lynch 2004). Marine life once included dugong (now absent) and turtles (rare and endangered) in numbers sufficient to support thriving fisheries (Oliver and Lynch 2004). Sharks are believed to have been more common in and around the lagoon (Wheeler 1953; Heemstra, Heemstra et al. 2004). Fishing activity historically has been heavily linked to market demand in Mauritius and characterised by maximisation of exports with little effective catch regulation (North-Coombes 1971). Over-fishing may date from the 1800s, when official records show that even with a population of around 2000

fisheries regulations being increased (North-Coombes 1971). Exports of fish to Mauritius have slipped to negligible levels since 1990 prompting rising local concern among fishermen and policy-makers over the state of the fishery (Gade 1985; CSO 2005). Rodrigues represents a useful case study site for determining how humans perceive changes in environmental state. Its marine natural resources have been poorly documented (Chapman and Turner 2004), biodiversity management is weak (Anon. 2005) and environmental management unsustainable (Anon. 2003). Fisheries data for Rodrigues is patchy and unreliable, although indicative of over-fishing (Edwards 2005; KPMG 2006). Fisheries management in small island developing states generally is poor (Mahon and McConney 2004). Mauritian fishers are marginalised (Hollup 2000) and fisheries in the region are used sub-optimally in poverty reduction strategies (Walmsley 2006).

Marine reserves and Marine Protected Areas

Rodrigues has begun work on one large Marine Protected Area (UNDP-Mourouk Project no. MAR/03/G35/A/1G/99) in the south (Figure 4). It has also gazetted four new

Figure 4: Map showing location of 4 marine reserves gazetted in northern Rodrigues in 2007 (left) and a preliminary boundary for a UNDP Marine Protected Area in the south (The main lagoon reef flat is denoted by the light grey area in the map marked 'reefs')



marine reserves in the north (2007) since regional autonomy in 2001 (Gell, Lynch et al. 2003; UNDP 2006). Both projects contain socio-economic development goals beyond biodiversity protection and fishery enhancement, with the UNDP project clearly committed to participatory management aimed at sustainable development. The island relies almost entirely on Mauritius for its budget (Anon. 2005). Fishing and tourism development pressure continue to rise in the coastal zone (Hardman 2004; UNDP 2006). Fishing is expanding to grounds beyond the main lagoon fishery which are partly covered by the new reserves (FAO 1998; Mauritius 2005).

3. METHODOLOGY

3.1 Surveys and interviews

Stratified random surveys with closed and open questions (Appendix 2a) were put to fishers in face-to-face interviews between August and September 2006 during 12 months of fieldwork in Rodrigues. Methods are described in data collection and sampling sections below. A mixture of research approaches were used, as recommended (Bunce, Townsley et al. 2000) for coral reef management contexts and social research in Africa (Bulmer and Warwick 1993). Two months of full-time participant observations were completed with three seine-net fishing teams ahead of the main survey to allow familiarisation with fishing methods, grounds, customs, concerns, as well as Creole language and lore. Semi-structured interviews in French and Creole were then recorded with head-seine fishers' and others identified by fishermen for their long-term knowledge of the fishery, its structure and trends. This and two months of participant observations of seine fishing allowed time to explore fishers' knowledge and allowed them to raise issues which they considered to be important. Such approaches can reduce subjectivity and have long been recommended when statistical findings are hard to interpret outside of a qualitative framework (Schwab 1954; Light and Pillemer 1982). The interviews helped guide the development

of survey questions aimed at quantifying fishers' perceptions of both the fishery and island-level environmental decline. Survey and interview design and conduct was based largely upon quantitative and qualitative research guidelines in Bunce, Townsley et al. (2000).

3.2 Data collection

The main survey included 93 active male Rodriguan fishers (total 1,269) from three age groups (18-29 years old, N=30, 30-49 years old, N=38 and 50-80 years old, N=25). To determine the extent to which fishers perceived Rodrigues' fishery to be in decline, and to identify signs of shifting baselines, respondents from the three generations of fishers were asked to list commercial species they believed to have been depleted during their lifetime (Saenz-Arroyo 2005). They also gave dates for the onset of each species' decline. This investigation was limited to commercial fish species most likely to have been caught by fishermen, including sharks as indicators of ecosystem health. Fishers identified species in decline using local Creole names with help from a standard local fish guide taken to all interviews (Terashima 2001). Comparisons were made between perceptions of decline of each species held by older fishers with perceptions of younger age groups. Respected senior fishers were asked to identify fish in decline whose lifecycles and predation habits meant they could be potentially useful indicators of coral reef fishery health and recovery at island level (Dulvy, Freckleton et al. 2004). Based on their answers extra survey questions were included on fishers' perceptions of decline of a specific predatory species of relevance to fisheries but also tourism, the White-blotched grouper *Epinephelus multinotatus* (Peters 1876; Heemstra and Randall 1993), also known as *Epinephelus leprosus* (Baissac 1968) and Vieille Plate (French Creole). Groupers are globally threatened by fishing. Fishers gave details of their best catch, both in terms of the largest single fish caught and the total number caught in a single fishing day (Saenz-Arroyo 2005). Fishers indicated the length of the largest grouper they had caught by showing a distance from their fingertips towards their

shoulder, or using the blank side of an unfurled tape measure if the fish was longer. Fish lengths rounded up to the nearest centimetre were converted to biomass using length-to-weight conversion values (Mathews 1987) with standard equations (www.Fishbase.org). To identify the extent of spread of fishery decline fishers indicated their perceptions of depletion of the lagoon compared to off-lagoon areas. During interviews and participant observations fishermen indicated their perceptions of the reasons for fish decline. They discussed how this was linked to island-level change, notably climate, coral decline, and deforestation linked to soil erosion and lagoon depth loss.

3.3 Sampling

The whole island of Rodrigues (pop. 38,000) was taken as the study area given its small size, tight land-sea interactions, the proximity and mobility of the island's scattered fishing communities and the geographical spread around the island of proposed Marine Protected Areas and reserves. There may be 5,000 fishers in Rodrigues (UNDP 2006) but to ensure validity the survey sample was based only on the 2,024 males and females registered as full-time professional fishers by Rodrigues' Fisheries Protection Service (FPS). Of these, 863 registered men (total 1,269) were identified as likely to be the most active based on FPS data on concentrations of boat and gear registration, and personal observations and fishers' comments. Despite their considerable contribution to the active and destructive octopus fishery, women's fishing remains largely restricted to octopus, hand-lining and general gleaning in coastal areas by foot. Men use boats and the full spectrum of gear to reach all grounds, in and beyond the large lagoon. This exposes them to a wider range species relevant to the research and over a longer period. No women were encountered in boats around the lagoon or outside in two months of participant observations. District census data from 2000 (CSO 2000) were used to adjust the final survey sample to population profiles at 10 selected fish landing stations, out of a total 23. Five to 10% of the targeted male

fisher population was interviewed at each location, with percentages rising for survey areas with smaller populations to retain statistical relevance. 93 fishers were surveyed at random at official landing stations or adjacent beaches, moorings and fishing camps, subject to the need to interview pre-determined numbers within each age group. Due to time and staffing constraints a few fishers were interviewed at home or on their plantations. Older and younger fishers at some locations were under-represented in official registers and it was necessary to interview some who were active but either unregistered or de-registered.

3.4 Data analysis

Quantitative survey data were analysed using standard non-parametric tests used in previous surveys (Saenz-Arroyo 2005) and available in standard SPSS statistical analysis programs. Qualitative comments in interviews were tabulated with unique fishers' codes indicative of age and interview location for later verification. Qualitative interviews were recorded digitally and transcribed in full. Fishers' comments were arranged by key themes, with quotes selected if they appeared to be representative of each fisher's views.

4. RESULTS

4.1 Social context

Rodrigues was settled comparatively recently and the worldviews of colonising Europeans and ex-slaves from Africa prevailed (Moore 1984; Eriksen 1994; Des Rosiers 2004). Together with later ascendant Catholic Creole culture in Rodrigues and Hindu-dominated national government these do not appear to have produced a notable conservation ethic in Rodrigues. A post-war population boom trebled the population to 33,000 by 1983, which has since stabilised at 38,000 through emigration (CSO 2005). Unemployment, poverty and illiteracy are all high compared to the main island of

Mauritius', which alone enjoyed an economic boom based on sugar, textiles and tourism (KPMG 2006). Fishing expertise has been reduced through emigration, government jobs, and less experienced entrants to the sector attracted by donor programmes and social security provision for registered fishers. Agriculture slumped after the 1970s and older fishers recall how less experienced inland communities once reliant more on farming increased their fishing effort due to drought, soil erosion, deforestation, water shortage and population growth. There is no notable traditional marine tenure system. Laws limit permits for fishers and some types of gear but open access generally prevails subject to increasingly available credit for equipment. Fish marketing prices are officially set but routinely flouted.

Politics tends to be authoritarian, and personality and clan-based. Island political power for over two decades has been largely dominated by a charismatic former Catholic priest, Serge Clair, whose fight for Rodriguan autonomy came to fruition in 2001. He lost power in 2005 amid fisher protests over his perceived role in overseeing a reduction in social security. Social problems are rising, including alcoholism and family breakdown (UNDP 2003). School failure rates are traditionally high (KPMG 2006). Efforts to bring Rodrigues into Mauritius' high-speed economic development include a new national focus on development of the large Exclusive Economic Zone (Persand 2005). Rodriguans are generally suspicious of mainland Mauritians, who in turn can be dismissive of Rodriguans as inferior. Ethnic tensions have eased on the multi-ethnic main island since Creole riots in 1999 (Eriksen 2004).

4.2 Fisher profile

Fishers start fishing as teenagers, seeking official registration as full-time professional fishers when allowed from the age of 18 onwards, to benefit from social security paid on bad weather days. The average fisher surveyed was aged 42, with 27 years of experience. Many fishers remain active well into old age and memories of the fishery

among those interviewed start in the 1940s. Fishers use a variety of gear, typically including hand-line (100%), metal and bamboo basket traps (80%) and spears or harpoons (76%), for octopus and large fish. Almost half of respondents had worked at some point in the seasonal large seine net lagoon fishery (March-October), which is in decline, but experience of seining rose to 72% for fishers aged over 50 years. Surveyed fishers were mostly active in the lagoon fishery (89%), where they are increasingly mobile, especially seine teams, middle-aged fishers and those from the more degraded north of the island (de Schutter 1999). A large majority of all age groups believe the lagoon fishery is already depleted (80%) and unable to meet local demand for fish. Fishers believe they have few other options but to move around within the lagoon and to grounds beyond, subject to investment in larger motorised boats or else joining larger commercial vessels operations mooted for the future. Around 50% of fishers interviewed fished in areas outside the lagoon, to differing extents, with some using poorly maintained Fish Aggregating Devices (FADS). In an effort to cut fishing in the lagoon youngsters are given fewer lagoon fishing permits and are encouraged to fish outside the lagoon or train for commercial licences. Older fishers have more commercial fishing experience with fleets elsewhere in Mauritius' large Exclusive Economic Zone (1.9 million sq kms), but fishers' comments suggest this makes them more efficient than conservation-minded. Overall, fishers perceive the fishery to be suffering from open access resource problems (96%), extending to land use issues (46%). All fishers surveyed professed to be in favour of conservation. A large majority see fisheries reserves where fishing is banned as necessary (87%). Even so, most fishers believe that poorly-defined and implemented coastal fisheries reserves used along the coast in the past had failed (88%), due partly to significant enforcement problems (62%). Fishers are distrustful of formal authority, whether central (75%) or local government (66%), and younger fishers appear less accepting of scientific advice than their elders (37% vs. 52%), although they are more likely to have been to school, and to have studied science under Mauritius' European-model syllabus (United

Table 4: Fishers' perceptions of fishery decline or depletion, and their outward expansion from the lagoon fishery to areas beyond the fringing reef

Extent of fishery decline	Fishers' perceptions (%) by area		
	Lagoon (N=87)	Off-lagoon (N=49)	All areas (N=93)
Fishery depleted and species lost	91	12	85
Fishery in decline only	9	65	15
Fishery stable or under-fished	0	23	0
	100%	100%	100%

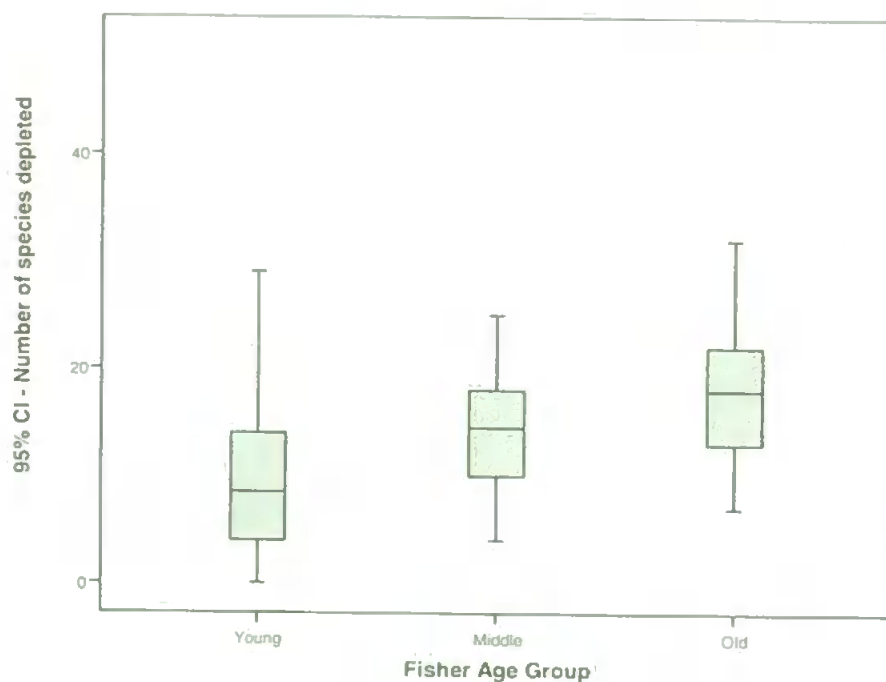
Kingdom's Oxford and Cambridge Examination Board). Younger fishers increasingly undergo formal government technical training to qualify for a licence but this is a recent development linked more to expanding off-lagoon fishing. Some Rodriguan fishers described learning to fish from their parents but older fishers decry the loss of even basic precautions, such as allowing juvenile fish and octopus to reach adult size, although fishers' comments suggest these rules were seldom routinely respected.

4.3 Fishers' perceptions of fish and fishing ground depletion

All but one fishers in the survey (N=93) cited fish depletion or loss of species, with concern focused on the main lagoon fishery. Altogether the 93 fishers perceived that a total of 95 species had been depleted in their lifetime, on average citing 13 species. Further analysis revealed clear inter-generational shifts in perceptions of species depletion and the extent to which the problem affected lagoon compared to off-lagoon areas where the government is increasingly encouraging fishing (Table 4).

Cross-generational differences in perceptions of fish decline were statistically significant. The median number of species reported (Figure 9 below) by the oldest group of fishers was 18, compared to 14.5 for the middle-aged and 8.5 for the youngest (*Kruskal-Wallis test, Chi-squared = 21.433, p = < 0.001, Std deviation: 8.441*). Older fishers not only cited more species as being depleted but also cited a higher number of years since the onset of decline. The average number of years of decline cited per fish

Figure 9: Number of species cited as depleted by three generations of fishers
 (Kruskal-Wallis test $\chi^2 = 21.4$ $p < 0.001$. Boxes show median, 5, 25, 50 and 95th percentiles of the data)



rose by around 5 years for each generation of fishers (Young=5 years, Middle Aged= 9, Old=15). For many species older fishers stated far higher numbers of years of decline. The oldest fishers cited a total number of years of decline for all species cited which on average was higher than members of the youngest group by a factor of 6.5 (Average: Young=46, Middle=135, Old=297). Overall, older fishers with more fishing years experience remembered the ecosystem as being in better condition.

Younger fishers very rarely reported more species depletion than their elders. For two-thirds of species a higher percentage of the oldest age group cited depletion compared to the youngest age group. In the case of 46 species, perceptions of decline rose without dipping through each generation up to the oldest. Only two young fishers reported no depletion of species.

Older fishers with more experience would have had more time to notice species and also their depletion. To improve the comparability of the fishers' perceptions across generations the number of species cited by each fisher was divided by the number of

years they had been fishing (Saenz-Arroyo 2005) to give a species loss rate both for each fisher and each age group. There was no significant difference in the loss rate between the three generations, suggesting no deceleration in depletion of commercial fish species (*Kruskal-Wallis test*, *Chi-squared* = 2.536, *p*=0.281). Perceptions of depletion of some species varied considerably around the island by fishing stations location. A total of 30% of younger fishers reported depletion of long-jaw Bonefish, *Albula glossodonta* (*Banane*), with fishers on average citing four years of decline, compared to 100% of the oldest group who reported an average of 20 years. Inter-station variation in fishers' perceptions of depletion of the species ranged between 40-87%. The deeper southern lagoon where the main MPA is planned appeared to be healthier in terms of lower loss rates and attracts more fishers from other areas than other zones.

Fishers consistently identified certain fish as depleted while uniformly showing less knowledge of whole families of other smaller or less-targeted ones, for example reef-attached Pomacentridae. Of the total 95 species identified by fishers, 54 were cited by all age groups. Older fishers were the most likely to remember greater abundance of the largest and most frequently cited fish, which younger fishers sometimes did not even recognise. Older fishers were most likely to remember an abundance of larger predators, in particular grouper and trevally (Serranidae and Carangidae). Grouper species (Serranidae) were most frequently cited as being depleted representing over 11% of the total 95. These included two fish species*** Peacock hind and Black-saddled coral grouper (*Cephalophelus argus* and *Plectropomus laevis*) which are included in surveys of endemic species in Rodrigues due to the general threat they face from over-fishing or over-harvesting (Hardman 2006). Younger generations had little or no knowledge of the former presence in the lagoon of these and many other species, with no young fishers at all reporting decline in the Eight-bar grouper (*Epinephelus octofasciatus*, *Creole: Vieille Farou*) compared to 40% of the oldest group. Older fishers and offshore fishers reported a continuing presence of some of

Table 5: Largest 25 species (cms) cited as depleted by three generations of fishers showing cross-generational variation in frequency of mention (% age group)

Family	Species (with usual Creole name given)	Age: Young Middle Old			
		Max (cms)	N=30	N=38	N=25
Elopidae	<i>Elops Machnata</i> (Lubine)	70	17	34	29
Albulidae	<i>Albula glossodonta</i> (Banane)	100	33	76	100
Mugilidae	<i>Mugil cephalus</i> (Mulet Voile)	120	3	5	24
Aulostomidae	<i>Aulostomus chinensis</i> (Trompette)	80	0	5	12
Serranidae	<i>Epinephelus octofasciatus</i> (Vieille Farou)	130	0	18	40
	<i>Epinephelus multinotatus</i> (Vieille Plate)	100	53	89	96
	<i>Plectropomus laevis</i> (Babonne)	100	10	16	48
	<i>Epinephelus polyphekadion</i> (Ciel du Bois)	90	3	8	40
	<i>Epinephelus radiatus</i> (Vieille Laboue)	70	0	8	40
Carangidae	<i>Caranx ignobilis</i> (Carangue Grosse Tete)	170	17	21	24
	<i>Gnathanadon speciosus</i> (L'Amoureuse)	110	13	34	36
	<i>Scomberoides lysan</i> (Sanspet)	100	0	3	4
	<i>Caranx melampygus</i> (Carangue Queue Jaune)	100	20	16	20
	<i>Seriola rivoliana</i> (Carangue de Fond)	70	0	5	4
Lutjanidae	<i>Lutjanus bohar</i> (Vara-Vara)	75	7	11	12
	<i>Lutjanus fulvus</i> (Sard)	70	3	3	28
	<i>Aprion virescens</i> (Vacoa)	70	7	5	8
Hemulidae	<i>Plectorhinchus chaetodonoides</i> (Carpe Calory)	70	0	0	12
Lethrinidae	<i>Lethrinus nebulosus</i> (Capitaine Normale)	80	23	28	12
Kyphosidae	<i>Kyphosus bigibbus</i> (Kongo)	75	13	8	24
Scaridae	<i>Chloratus strongylocephalus</i> (Cateau Vert)	70	13	13	4
	<i>Scarus ghobban</i> (Cateau Blanc/Rose)	70	10	0	12
Sphyraenidae	<i>Sphyraena barracuda</i> (Gros Thazar)	170	7	11	12
Muraenidae	<i>Gymnothorax undulatus</i> (Lamandia)	150	3.3	0	0
Acanthuridae	<i>Naso unicornis</i> (Licorne Vache)	70	6.7	5.3	0

these species in areas increasingly further offshore. Older fishers remembered catching species from coastal fishery reserves and beach waters which they now perceived to be devoid of them, for example black-tail snapper (*Lutjanus fulvus*, Creole: Sard). They recalled days when large fish and sharks could be hunted down by harpoon on foot or from sailed pirogues. Such observations were indicative of general perceptions of fishery depletion radiating outward from the shore to more distant fishing grounds, although fishers in participant observations still gave excited chase to large fish rarely encountered in the lagoon, including one Giant Trevally (*Caranx ignobilis*).

However, the largest fish, often the most vulnerable to depletion, were not generally the most frequently cited as being as such. Only three species appear both in lists of the largest 25 fish (cm) reported to be nearly or totally depleted (Table 5 above) and the top 25% of fish in terms of frequency of mention (Table 6). These included the white-blotched Grouper* (*Epinephelus multinotatus*, Creole: Vieille Plate), and two species associated by fishers with depletion of coastal fisheries with marine reserves which had reportedly failed to protect fish and their juveniles from fishers - the roundjaw bonefish *Albula glossodonta* (Creole: Banane) and the ten-pounder, *Elops machnata* (Creole: Lubine). Fish associated by fishers with depletion of coastal fisheries were among the most frequently cited as in decline, including French sea bream (*Rhabdosargus sarba*, Creole: Gueule Pave), ten-Pounder, small-spotted dart (*Trichonotus baillonii*, Creole: Carangue Moulon), striped threadfin (*Polydactylus plebeius*, Creole: Barbet) and yellow-striped goatfish (*Upeneus vittatus*, Creole: Rouget Marque or Rouget l'Herbe).

Table 6: Species most cited as depleted by three generations of fishers, ranked* by frequency of mention (%) and showing cross-generational difference (age group)

Rank	Species	Creole name	Length (cms)	Young (N=30)	Middle (N=38)	Old (N=25)	Average	Yrs decline (ave)
1	<i>Epinephelus multinotatus</i> *	Vieille Plate	100	53	90	96	79	12
2	<i>Rhabdosargus sarba</i>	Gueule Pave	60	43	76	84	68	11
3	<i>Albula glossodonta</i>	Banane	100	33	76	100	68	14
4	<i>Trichonotus baillonii</i>	Carangue Moulon	50	43	71	72	62	4.6
5	<u>Uncertain</u> * - like <i>R. sarba</i>	Pierre Aboire	50*	27	74	76	60	14
6	<i>Cephalopholis argus</i> ***	Cuisinier	40	50	55	68	57	10
7	<i>Plectorhinchus picus</i> **	Carpe Carolisse	50	20	68	68	52	12
8	<i>Platax orbicularis</i>	Poule d'Eau	45	30	53	60	47	9
9	<i>Epinephelus macrospilos</i>	Vieille Voleuse	50	17	55	64	44	12
10	<i>Polydactylus plebeius</i>	Barbet	50	30	50	44	42	10
11	<i>Upeneus vittatus</i>	Rouget Marque	28	13	34	52	34	10
12	<i>Selar crumenophthalmus</i>	Carangue Maquereau	60	13	37	44	33	9
13	<i>Lethrinus harak</i>	Battardet	50	23	45	28	33	9
14	<i>Xyrichtys pavo</i>	Cateau Bosse	40	23	29	40	29	11
15	<i>Elops Machnata</i>	Lubine	70	17	34	40	29	10

*Before rounding up decimals to nearest figure

Table 7: Older fishers' interview comments on depletion of a grouper (*Epinephelus multinotatus*, Creole: Vieille Plate) potentially indicative of marine reserve success

Fishers	Comment
Old fisher	<i>Vieille Plate. No there is nothing – since the octopus fishers started to march to walk about the lagoon, with a wire rod (1980s).</i>
Old fisher	<i>We haven't seen many for quite a few years. Even when the fishers fish to the bottom occasionally, there is still not much.</i>
Old lagoon/off-lagoon fishers	<i>... 1960s ... And the Vieille Plate – that is a long story! Before, people hunting octopus in the lagoon would sometimes also take 50 pounds of Vieille Plate with a harpoon. And then the line fishers, seine fishers. And the basket fishers also used to take a lot! The Vieille Plate disappeared a lot.</i>
Middle-aged fisher	<i>Vieille Plate ... that has gone down too. I would say over about 10 years (chuckle) ... in one hour you would catch 25 kilos. The problem is that all the big corals were at the surface – they like the coral – but then all the coral got covered with sand. Either they went away or they died.</i>

Fish only recently recorded in Rodrigues were also among those most frequently reported as depleted – the Painted sweetlip (*Plectorhinchus picus***, Creole: Carpe Carolisse) (Heemstra, Heemstra et al. 2004) is a solitary species inhabiting lagoon and seaward reefs. Just 20% of youngsters reported its decline, compared to 68% of each of the two older groups.

*4.4 Fishers' perceptions of decline in indicator species (*Epinephelus multinotatus*)*

The white-blotched grouper was cited more than any other species as depleted but youngsters half as likely (47%) than the oldest fishers (96%) to have caught one, and some did not even recognise it. Based on their own perceptions, older fishers were more likely to have caught larger fish (Figure 10) and landed more of them (Figure 11) on their best day ($p < 0.005$ in both cases). They recalled catching up to 10 on their best day, on average 23 years ago, compared to an average best of 6 fish caught 3 years ago by youngsters. Older fishers reported decline of the grouper in the lagoon over a 25 year period (Table 7), prompting fishers to pursue them far out to sea in small open boats:

"There were a lot ... where the continental plateau leads to the deeps ... We took the big ones out there ... (10- 20 kilos) and they took the little ones here (in lagoon) ... They really began to decline in 1995. We over-fished them".

Figure 10: Range and mean estimated weights of largest white-blotched grouper landed by three generations of fishers recalling their best ever day's catch (one-way ANOVA, $p < 0.001$, LSD, groups significantly different $p < 0.05$)

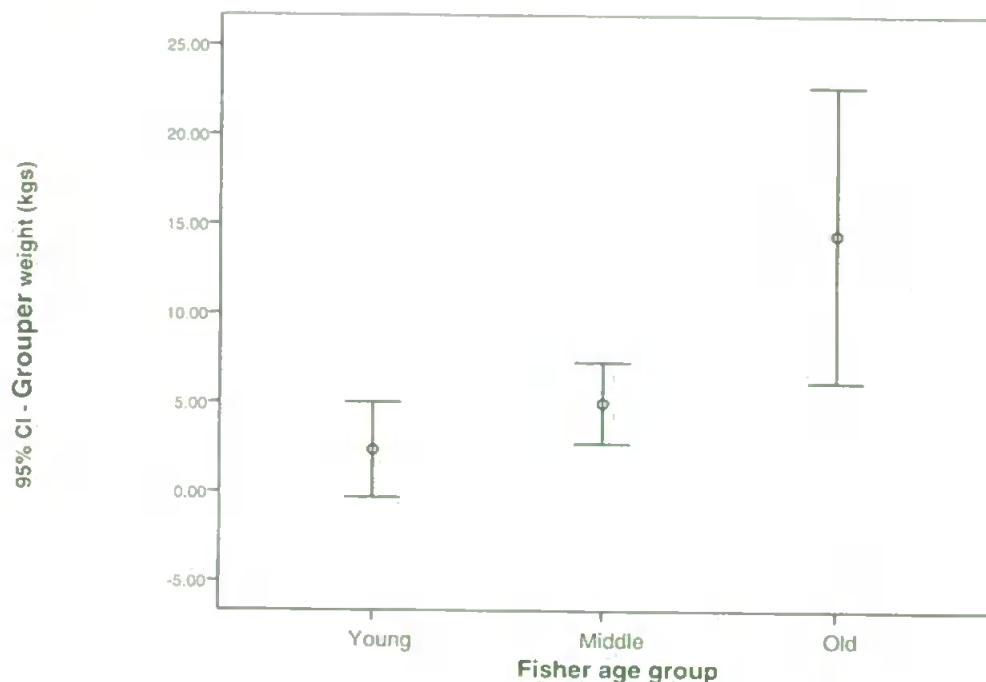
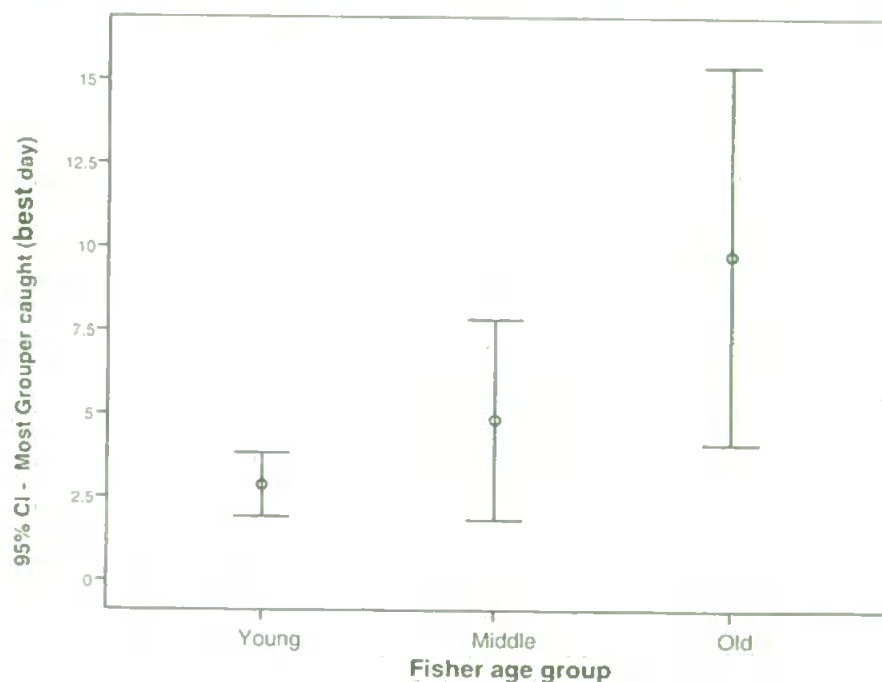


Figure 11: Range and mean of highest number of white-blotched grouper caught by three generations of fishers recalling their best fishing day (One-way ANOVA, $p < 0.001$, LSD significant difference between Old and Young age groups, $p < 0.05$)



White-blotched grouper are to be found at the top of food chains, playing a major role in the structure of coral reef communities (Randall 1987), and have been described as relatively common in reefs of the South-western Indian Ocean (Teleki 2000; Grandcourt 2002; Robinson, Isidore et al. 2004). Grouper are vulnerable to fishing gears (Munro 1985), and can be easily overexploited to the point of being wiped out in a few years (Johannes 1998; Johannes 1999). Older fishers had better catches even though they were less active in off-lagoon areas, where their comments suggested groupers form spawning aggregations in need of protection in sites beyond current reserve boundaries. Such comments underline the need for far greater consideration of fishers' existing local ecological knowledge than presented in this paper.

4.5 Fishers' indications of decline in top predators (sharks)

Fishers in pilot interviews found it hard to distinguish between similar species of shark and commented instead on their general presence, formally recorded in the 1950s (Wheeler 1953) (Table 8 below). Cross-generational differences emerged in fishers' perceptions shark presence in the lagoon. A total of 22 (n=93) fishers reported decline, including 13% of youngsters, 32% of the middle aged group and 24% of older fishers. Species named included white- and black- tip reef sharks (identified as *Triaenodon obesus* and *Carcharhinus melanopterus*), Hammerheads (*Sphyrna lewini*), grey sharks (*Carcharhinus amblyrh*), bull sharks (*Carcharhinus leucas*), and tiger sharks – identified usually as *Galeocerdo cuvier* or *Nebrius ferrugineus*. Some of these identifications may be erroneous; *Carcharhinus melanopterus*, for example, is easily confused with *C. brevipinna* (Heemstra, Heemstra et al. 2004). Even fewer middle-aged (3%) and older fishers (8%) reported decline in the lagoon of species of ray. Those identified included electric (*Daysatis kuhlii*), flap-nose (*Rhinoptera javanica*), honeycomb (*Himantura uarnek*) and white-spotted eagle rays (*Aetobatus narinari*).

Table 8: Older fishers' perceptions in interviews of shark species reduction in Rodrigues' main lagoon fishery

Old fisher, all areas (born 1930)	<i>No! There used to be little sharks going about in the lagoon, sharks and rays everywhere in the lagoon. But sharks now? No! (since) a while ago – in the 1970s Where people put their traps (sharks came to) get the little fish And then in the lagoon they came after giant trevally... (C. ignobilis)</i>
Old fisher (born 1935)	<i>Back in the 1940s you had sharks in the lagoon all the time – in North Bay and Oyster Bay, for example. The lagoon filled up after that but it is hard to say in which year. Fish have stayed outside the lagoon since (1974.)</i>
Old lagoon fisher (born 1935)	<i>(sharks) still come in, but not like before...in a week you could catch three (1950s). MPB: They have disappeared then? Yes – no fish.</i>
Old lagoon fisher (born 1940)	<i>A lot were killed – it is not like before</i>
Middle-Aged fisher (born 1955)	<i>When there are problems in the lagoon they just go deeper, outside the lagoon. And when the reef is restored they can come back in ...we have caught them</i>
Middle-aged fisher (age ?)	<i>Sharks sometimes chase fish up the channel</i>
Middle-age fisher (born in 1966)	<i>Apparently in the past, when the lagoon was deeper, (sharks) used to come in to release their young....But now it is shallower and they do not come in.</i>
Middle-aged fisher (born 1960s)	<i>The fish know the zones where they will be targeted. They know where there are no baskets and where there is no fishing – and they will go there. Sharks, tortoises go to those places. They know places which are fished. If the fishermen go there they will not.</i>

One older fisherman remembered his father fishing from floating logs in fear of his legs been bitten off by sharks within the lagoon:

"Even he said he wanted to give up his trade because it was hard ... the open sea, sharks, breaking traps. You were always starting over again."

Overall, fishers' noted the gradual absence of sharks in the lagoon while reporting sharks still snatching fish from fishing lines, spear-gunning divers and even boats at the outer reef slope. Two sharks reported as depleted appear as endangered on IUCN's Red List for Mauritius – the Oceanic White-tip (*Carcharhinus longimanus*) and Giant guitarfish, (*Rhynchobatus djiddensis*). Fishers' perceptions support Heemstra's view that chondrichthyans have been reduced by fishing, in line with other Indian Ocean

localities, but more research on their presence is needed. Two non-fish species on the List were reported as depleted – the Green Turtle (*Chelonia mydas*), and the Small Giant Clam (*Tridacna maxima*). Octopi were not included in the survey but their severe depletion is locally reported in unpublished data (Lynch 2005).

4.6 Island-level environmental decline

Although this study focused on depletion of commercial fish, fishers also answered survey questions on wider environmental degradation at island level on land and at sea. Shifting baselines were evident in fishers' perceptions of the wider environment, including cyclonic climate patterns affecting water scarcity, tree and coral cover and lagoon depth. Fishers' perceive the lagoon to be impacted by land degradation which continues due in part to the effects of deforestation, long-standing and continuing uncertainty over land tenure, grazing rights and other open-access resource issues, which in the past have been described as Rodrigues' "Tragedy of the Commons" (Gade 1985). Their comments in qualitative interviews indicated a local understanding of the tight interactions between human and natural drivers of change on islands on land and at sea (Table 9 and 10). Older fisher's recalled episodic coral die-back over decades, linking its severity to fishing but also climate and human activity on land.

Table 9: Perceptions of fishery decline and environmental change (% of age group) among three generations of fishers (Young, Medium, Old)

Environmental change on land and sea	Y	M	O	Ave
Tree cover has reduced over lifetime	63	63	88	71
Droughts have become more common	43	61	72	58
Cyclone patterns have changed	93	97	100	97
Lagoon has become shallower	83	97	88	91
-- leading to typical water column loss (feet)	1.8	2.9	3.3	2.7
Periods of severe coral death	77	89	100	88

Table 10: Selected fishers' memories in interviews of fishery decline in Rodrigues Island

<i>Retired fisher:</i> In the 1920s people saw there were almost no fish left ...so they abolished (seine) fishing but there was so much fraud that eventually, by 1939, it was legalised with rules (not observed)
<i>Old fisher:</i> At that time (post-war) there was over-fishing too! (When father) came back from the war, '46, '47, '48, there was no concern. We took large quantities of undersized fish
<i>Old head seine fisher:</i> In the 1960s there were a lot of fish ... More and more the fish are in decline.
<i>Coast guard:</i> In 1974, we had a huge drought, due to deforestation. The more they killed the forest, the more the exodus to the sea was accentuated.
<i>Old fisher:</i> There have been three heat waves ... the fish died in the lagoon and floated. The eels as well. (During) the big (1970s) drought, there was no wind, the tide was low and there was a lot of sun. The temperature was not right for the fish.
<i>Old head seine fisher:</i> The sea and the land have changed greatly. We fishers – in our experience the sea, and the land work in the same way. They both need rain. (Rains did) not stay normal. In the 1950s there was a lot of rain and even if you planted the maize or potatoes on rock or stone you'd get some. But then later on ... we planted an acre of maize and got 70 sacks of maize. Now you can plant an acre and you get only get 10-15 sacks.
<i>Old seine team head:</i> Cyclones – a lot of cyclones came! And took all the dirt from the land and canals and put it in the (sea) depths. And dead coral got crushed into sand
<i>Middle-aged seine team head:</i> The channels filled up, where the Gueule Pave (fish) were happy, and a lot of coral and sea bed areas. When the coral dies it is finished. It is finished, because they like beautiful coral where they can hide inside. And perhaps in the channel too, they were happy in the depths, but there is no depth left.
<i>Government fisheries worker:</i> Completely different now, the sea. We used to have a lot more fish and a marine environment – (with) loads of coral ...in some places there is none left.
<i>Middle-Aged fisher:</i> There was a lot more coral. Fishing was good (1970s)...but a lot less now. There was too much activity in the lagoon (1980s). All kinds of fishing, not just seine. It is still going down.
<i>Middle-aged sine fisher:</i> Coral was living but now it is dead. There are no longer small fish in the coral. Before, the big fish came to eat the small fish. Parrotfish ... live on the reef bar ...if you look at the reef bar there is no longer anything to graze.
<i>Old seine fisher:</i> Fish used to stay on the coast when they were young. Now they stay further away.
<i>Middle aged fisher:</i> (Sea temperature rise) started about 15-20 years ago. It has killed a lot of coral – it makes the fish go. The sea has lost 30 cms (depth) and that continues ...
<i>Retired fisher:</i> There are still a lot (of fish) outside the reef but they can't come back in. So maybe they will be like the turtles. Go and find shelter somewhere else or they are finished.
<i>Commercial offshore fishing boat owner:</i> The lagoon is overexploited...about 5 years. The catch has not been enough for the population.
<i>Middle-aged seine fisher:</i> We need to fish outside the lagoon ... but Rodrigues' fishers are different to those in Mauritius. We have bigger seas. Money needs to be spent on ... big boats
<i>Retired government worker:</i> The (offshore plateau) banks. If we do not look after those and create jobs for fishers then in my opinion we will draw on that as a reserve. At that point the kind of excess that we have already seen here and we will exhaust them too.
<i>Old fisher:</i> I have six sons and four of them are fishers. But they are wasting their time as the fish have gone away
<i>Middle-aged fishers:</i> It's every man for himself. That is the life of the fisherman!
<i>Old fisher:</i> If we continue our children will have nothing ...

Results limitations

Results presented were confined to common commercial fish. It was not possible in this study to cover the full breadth of biota typically found in a large coral reef fishery.

Rodriguan fishers might have mentioned more species and perhaps endemics if surveys and classification of species had been completed, with fish guides adapted to the island.

Rodriguan fishers' perceptions of fish species decline contained anomalies. Older fishers did appear to have caught bigger fish but some of their estimations of lengths of landed grouper were up to 40% in excess of currently acknowledged adult limits (100 cm) (Terashima 2001). It is possible that current guides do not reflect longer fish lengths found in the past – a form of shifting baselines by itself. A determination of length to weight conversion values specific to grouper in Rodrigues would help clarify the current discrepancy. Such estimations could also be due to other factors, including poor memory, bravado, illiteracy and innumeracy (UNDP 2003) or just the general human tendency to construe the past in a favourable light.

Interpretations of cross-generational perceptions of decline and determining shifting baselines are problematic. The best indication of decline appeared to be higher perceptions of depletion among older generations compared to younger generations, regardless of frequency of mention, coupled with low or absent recognition of species among youngsters. Overcoming uncertainty was assisted by participant observations, qualitative interviews and the use of clear photographic fish guides.

Compared to longer-settled Pacific island fishing communities described by Johannes (1978) Rodrigues lacks both a systemised body of local ecological knowledge and taboos or a mechanism for handing down such knowledge through generations. This reduced scope for bringing longer term ecological knowledge into this study for comparisons between fishers' perceptions of present and more distant past states of the fishery and island environment.

5. DISCUSSION

5.1 Key issues

5.1.1. Evidence of shifting baselines in fishers' perceptions of Rodrigues' fishery

Shifting baselines (Pauly 1995) are apparent in fishers' living-memory perceptions of fish species decline in a mixed artisanal coral reef fishery. Results from Rodrigues support the outcomes from the only other quantitative study in the very different context of the Gulf of California (Saenz-Arroyo 2005). Cross-generational differences in Rodriguan fishers' perceptions of depletion of large predators, including groupers and sharks, are indicative of fishery decline but also ecosystem impairment (Myers 2003; Myers 2007). Results support earlier reports of over-exploitation of Rodrigues' fishery and damage to coral (Montaggioni 1978; Pearson 1988; Hardman 2005), and the possibility of unreported past episodes of coral bleaching (Hardman, Meunier et al. 2004).

5.1.2. Island level significance

A lack of historical environmental data for the island of Rodrigues hinders evaluation of the impact of past removal of any single species, including predatory sharks, groupers and whales (Hughes, Bellwood et al. 2005). However, it is reported that the depletion of functionally important consumer species such as grouper can indirectly influence coral reef ecosystem structure and function even at the scale of islands such as Rodrigues (Dulvy, Freckleton et al. 2004). Rodriguan fishers' appear to have an understanding of close land-sea interactions processes and their negative impacts, which in turn may limit scope for future sustainable development on the island and entrench pressure on the fishery when it can least support it (Kerr 2005). Ultimately, rising human and natural pressure could already have reduced the capacity of

Rodrigues' isolated reefs to regenerate and supply coral larvae contributing to growth of distant Western Indian Ocean reefs.

5.1.3. Shifting baselines in data-poor MPA development contexts

Shifting baselines among fishers implies a reduction in what they expect of a fishery. The need to reset expectations for conservation on land and sea is referred to in earlier shifting baselines studies (Saenz-Arroyo 2005) and applies to mixed coral reef fisheries such as Rodrigues. This appears to have been achieved through the use of marine reserves established over a long period in the Philippines. Reserves established on a No-Take basis (NTZ - excluding fishing and other extractive use), appear to have thrown shifting baselines into reverse through positive demonstrations of ecological impacts on habitat and fishery yields (Alcala and Russ 2006). A "considerable psychological impact of enhancing support for reserves within the local community" reported from the Philippines may be needed in Rodrigues to overcome resistance to reserves that can be associated with shifting baselines (Bohnsack 2003). Fishers' perceptions do not need to be objectively "true" to be useful in promoting a working consensus between fishers and also with scientists on the status of the fishery against which to measure future change. Rodrigues' fishers already recognise the depletion of large predatory groupers, which in turn are indicators of ecosystem health (Myers 2005; Mumby 2006; Myers 2007) useful for measuring the impacts of reserves in Rodrigues (Edwards 2005) and generating tourism revenue through marine park entry fees (Rudd and Tupper 2002; Halpern 2003). Such commonality between fishers and policy makers is needed in Africa, where an absence of scientific baseline data against which to measure long-term changes is reported to have complicated demonstrations to users, such as fishers, of the success of Marine Protected Areas and reserves in conservation and biodiversity terms (Francis, Nilsson et al. 2002; Francis and Torell 2004).

5.2 Policy implications

Without effective corrective action there is a risk of further environmental degradation coupled with depletion or even extinction of marine species around Rodrigues (Jackson 2001). The island's fishery already is most likely to be in decline on the basis of evidence presented here, while coral reefs in the region face not just local but external threats from remote human stressors and climate (Abram 2003). Whether or not mainly due to fishing, coral degradation raises the risk of future biodiversity decline and loss of resilience even in marine reserves that are established (Jones, McCormick et al. 2004).

This study underlines the importance of understanding fishers' local knowledge in MPA contexts linking fisheries with wider development (Johannes 1998; Aswani and Hamilton 2004). Fishers' expectations may ultimately influence the capacity of the island's ecosystem to absorb recurrent natural and human perturbations (resilience)(Hughes, Bellwood et al. 2005; Hughes, Bellwood et al. 2006). Fishers are often farmers in Rodrigues and their historical knowledge crosses land-sea interfaces. MPA are rarely built on scientific decisions alone (Alcala and Russ 2006) and fishers' expectations need to be understood as they make difficult shifts from damaging traditional fishing livelihoods to economic alternatives linked to protected area policy (Rodwell and Roberts 2000; Christie, Fluharty et al. 2007). An increasing number of practical case studies illustrate ways to make use of local knowledge (Folke 2004) and an exploration of fishers' knowledge within adaptive management frameworks could help Rodrigues avoid repeating the failure of other island MPA (Rogers and Beets 2001).

5.2.1 *Integrated response*

The use of Marine (and Coastal) Protected Areas set within an overarching Integrated Coastal Zone Management (ICZM) structure would seem appropriate to the island's

small size and tight feedbacks between the impacts on the ecosystem of human and natural stressors on land and at sea (Cicin-Sain and Belfiore 2005). An inclusive approach to MPA management would provide an opportunity to build up social resilience through bottom-up management consultation processes running counter to Mauritius' and Rodrigues' top-down tendency. This could be costly and time-consuming, but, If successfully implemented, MPA could help change Rodriguan fishers' declining expectations from their fishery and build support for conservation.

5.2.2. Risks of multiple objectives

Fishers in degraded environments would appear to have little to lose through protection of their environment, particularly if they can at the same time generate considerable sideline revenue from reserve-related tourism (Alcala and Russ 2006). However, Rodrigues faces the conundrum of many small islands. Development options based on linking biodiversity to tourism as an alternative to more traditional economic activities such as fishing can still quickly expose shortcomings in island resource bases (Moberg and Folke 1999; Ramessur 2003; Sealey 2004; Sobhee 2006). Multiple goals attached to protected areas to foster sustainable development in Rodrigues could reduce their ability to fully restore lost biodiversity (Dietz 2003) and reduce their relevance to larger ecosystem management imperatives (Payet 2005). Large no-take areas may be needed within MPA boundaries and perhaps beyond to promote functional resilience of the island's reef system and fishery, or any sustainable development goals may prove elusive.

5.2.3. Building social resilience

Shifting baselines reflects a loss of social memory and therefore degraded social resilience. In more traditional social systems than Rodrigues, knowledge may be preserved for several generations by oral tradition but even this is being lost in the face

of mass media. Official policy in Rodrigues could start by compensating for systemic memory loss by providing materials describing key aspects of the island's environmental past, including how and why lagoon states have changed (Johannes 1978; Johannes 1998). These could be integrated into formal education to increase buy-in to corrective policies, including MPA. Rodrigues has a top-down political culture with little effective experience of participatory processes and chronic fishery enforcement problems. Until now outsiders have dominated the island's policy, whether distant colonial and subsequent Mauritian governments, or donors whose advice contributed to rapid expansions of fishing. The Regional Assembly plays an increasing role but suffers from a lack of capacity and reliance on outside officials. The challenge to building local social as well as ecological resilience is considerable, but Rodrigues' fishers are aware of declining catch and income and outwardly prepared to give reserves another chance. The Philippines model of successfully mixing fisheries reserves with the development of alternative incomes suggests this is possible option (Alcala and Russ 2006).

5.2.4. Recovery trajectories

In the long-term, fishers' perceptions of ecosystem recovery may need to be understood as much as their perceptions of decline. The outcomes of MPA are unpredictable and may not recover along the trajectory of decline, yielding a different environment to the one lost. Past ecological states may never be recovered, or even be desirable. However, such hysteretic effects (Hughes, Bellwood et al. 2005) could mean fishers are disappointed by results and doubtful of policies such as MPA.

5.3 Future studies

Future studies on shifting baselines might consider the need to include functional resilience in ecosystem management plans, which biodiversity conservation alone may

not ensure (Hughes, Bellwood et al. 2005). Further explorations of fishers' knowledge may help determine if current MPA and reserve boundaries protect essential biodiversity and ecosystem functions at island and regional level. The presence and effects of removal of top predators such as sharks around Rodrigues needs further study. Local vessels catch sharks on Rodrigues' fishing Banks (East and Hawkins), which fishers' comments suggest are natural fish sanctuaries in need of protection. The presence of whales visible from the coast is also little studied in the region (Payet 2005). Overall, there is a need for better information on the history and trajectories of state change in Rodrigues' social and ecological systems to cope with over-exploitation and impacts on land and sea amplified by climate change (Munasinghe 2001; Thatje 2006).

6. CONCLUSIONS

This paper details findings of the first quantified evidence of shifting baselines (Pauly 1995; Pauly, Watson et al. 2005) in fishers' perceptions of the state of an island reef fishery. Such evidence is a form of local knowledge which contains clues for successfully establishing MPA to build social and ecological resilience (Holling, Carpenter et al. 2004) in data-poor areas of Africa and beyond, particularly when degradation may be rapid but time and funds for scientific understanding are limited. (Johannes 2000). The perceptions of fishers in Rodrigues suggest they understand linked environmental change on land and sea that may need to be addressed at island-level through adaptive management approaches bringing social-ecological resilience concepts into discussions of sustainable development. The knowledge presented here may not equate to scientific truth as it is based mainly upon perceptions. Further studies would allow for more meaningful comparison of evidence of shifting baselines from different regions and cultures. Experience suggests MPA outcomes are subject to fishers' perceptions and expectations and to that extent these need to be heard and considered for their merit and relevance to policy. Worldwide coral reef fisheries have

been described as “under siege” from over-fishing despite their enormous economic, social, cultural and aesthetic value (Hughes, Bellwood et al. 2006). Johannes reminds us that under conditions of great uncertainty it is sometimes the fruit not the root of conservation and fisheries management that matters.

CHAPTER 5

Local knowledge emerges as a component of social-ecological knowledge that may be useful in determining impacts of Marine Protected Areas (MPA) and for building support among resource users leading to compliance. By highlighting decline of large species with critical ecological function, and of commercial interest to fishers and tourists, there is a demonstrated incentive for protecting such species in MPA as a sustainable development option. Chapter 5 develops these issues in more detail, starting from the standpoint of a need to enhance the financial resilience of conservation. This chapter presents survey findings on tourists' willingness to pay (WTP) to use land and marine protected areas (MCPA), and contextual qualitative findings from interviews with other stakeholders in natural resource management. WTP is not presented here as broad strategy for valuing ecological goods and services but as a practical policy strategy for funding conservation in an economically dependent island seeking sustainable development. This chapter highlights potential but also constraints connected to tourism development and related MPA fee generation.

CHAPTER 5

TOURIST USER FEES FOR SMALL ISLAND CORAL REEF MPA

Key words - Diving, French-speaking, willingness-to-pay, ICZM, branding, development

1. Abstract

French-speaking islands of the Indian and Pacific Oceans have reportedly low tourism fee-raising potential from their Marine Protected Areas (MPA), due partly to a lack of fee structures and poor management. This chapter addresses a lack of case studies of fee potential for such islands, focusing on the French-Creole speaking island of Rodrigues (Mauritius) in the Indian Ocean as it began setting up two types of MPA – one with a land element and four without. A survey of 351 tourists showed they were willing to pay 7 euro/week (median) to use a future Marine and Coastal Protected Areas with a large land element (McPA). Divers (167) among the visitors were potentially willing to pay more (depending on dive frequency) at 3 euros/daily to use a Marine (only) Protected Area (MPA) - regardless of any land element. Potential diver fee revenues (300,000+ euro) compare well with global benchmark MPA, for example at Apo island in the Philippines and Bonaire in the Caribbean. Fees could be levied at MPA but also potentially island-entry level as in Galapagos. However, diving is little developed. Visitor trip motivations were general, and focused more on nature, people and tranquillity than activities. Tourism is also dominated by French nationals with the lowest WTP compared to other visitors. The reasons for this were unclear, but not strongly correlated with low ratings of island environmental state. French tourists' comments suggested that their government's tradition of high taxes and centralised planning could be an issue creating resentment of "tax" overseas. More studies may reveal if this pattern is generalised. Overall, better access, a wider tourist base, mixed fees, insights into WTP motives and MPA-centred island branding for coastal management could help remote islands earn sustainable funding for conservation.

2. INTRODUCTION

2.1 Coral reef resilience

Beauty and biodiversity help coral reef systems provide humans with renewable and non-renewable ecological goods and services (Moberg and Folke 1999). Threats to reef survival worldwide from land and sea include distortion of food webs from above, including over-fishing, and addition of nutrients from the bottom, leaving climate change, new diseases and "other human-caused impacts" to do the rest (Hughes, Bellwood et al. 2006). The cross-scale use of Marine Protected Areas (MPA), either

multi-use and/or no-take (no extractive uses), is proposed for building coral reef and fisheries resilience (Hughes, Bellwood et al. 2005; Roberts, Reynolds et al. 2006).

2.2. MPA and coral reef tourism

MPA are often set up for two related purposes; wildlife conservation and fisheries management. Tourism benefits as a third driving force (Glover and Earle 2004). Growth in nature-based tourism exceeds tourism's globally upward growth trend (Nyaupane, Morais et al. 2004). Marine and coastal tourism is one of the world's fastest growing activities (Hall 2001). Tourists seek recreational amenity on reefs (ISRS 2004), of which 75% are in developing countries (Wilkinson 2004) where there is already pressure on reefs from growing populations dependent of them for food and livelihood. Tourism can clash with reef conservation and other MPA goals, leaving other MPA stakeholders marginalised (Christie, McCay et al. 2003) and breaking MPA rules. In Africa, there is an additional and long-standing risk of conservation displacing people (Hulme and Murphree 1999; Schroeder 1999).

2.3 Tourism risks to small islands

Exponential growth of tourism and its spread to the remotest regions of the world raises paradoxes in nature tourism (Hillery, Nancarrow et al. 2001). Tourism revenue increasingly outstrips earnings from traditional fishing in islands (Lutchman 2005). Of the 31 countries with over 20% of their Gross Domestic Product generated by travel and tourism, 27 are island states (AOSIS 2005). However, small islands face tight feedback loops between environmental stressors and drivers on land and sea (Kerr 2005). Feed-backs of tourism can quickly exceed the social and environmental carrying capacity of small islands, reducing recreational amenity and revenue upon which it so often depends (Arrow, Bolin et al. 1995; Brown, Turner et al. 1997). Islands contain 12 of the world's 18 global centres of endemism for coral reefs and seven of the world's

global coral reef hotspots (Lutchman 2005). Islands with fringing reefs are particularly prone to development risks (Gomez 1997).

2.4 Financial constraints to Integrated Coastal Zone Management (ICZM)

The close links between human activities on land and sea have fostered interest in building land elements into MPA to create Marine and Coastal Protected Areas (Cicin-Sain and Belfiore 2005). This is particularly relevant to tourism in small islands (Dixon, Scura et al. 2000), which often proceeds with “sustainability” otherwise left open to wide interpretation (Miller and Berno 2006). However, ICZM and MPAs face unsustainable government or donor funding limited to set-up phases, leaving projects with self-financing difficulties (Dharmaratne, Yee Sang et al. 2000; McClanahan, Mwaguni et al. 2005). The tourism sector in East Africa has been a driver for MPA and ICZM establishment due to a recognized importance of biodiversity to tourists (McClanahan, Mwaguni et al. 2005) but funding remains a critical limiting factor for effective management of many African MPA in the Indian Ocean (Francis and Torell 2004).

2.5 MPA tourism fees potential for funding

Viewing wildlife provides economic value to participants as part of terrestrial and marine tourism industries, raising scope for funding from user fees in protected areas (Spurgeon 2006). This includes divers. Coral reefs attract rising numbers of divers (Green and Donnelly 2003), despite the physical damage they cause, for example by kicking coral with fins (Barker and Roberts 2004). Some longer-standing MPA, for example at Apo Island in the Philippines, report clear fisheries benefits but also tourism revenues of around \$100,000, with an extra \$35,000 from divers paying to use the reserves (Alcala and Russ 2006). Socioeconomic status, cultural ties and past experiences influence how such people perceive environmental quality (Bird 1996),

which in turn can influence tourists' WTP for use and non-use amenity. The national economic impact (Archer and Fletcher 1996) and ecological footprint of tourism in some small islands in the Indian Ocean region (Gossling, Hansson et al. 2002) has depended heavily on patterns of market preferences among visitors of different countries.

2.6 Aims and objectives

2.6.1 Regional gap in MPA user fee potential

Published studies of the relevance and application of diver and other tourism fees have focused on English-speaking contexts in the Caribbean and Asia, where a lack of sustainable self-financing has contributed to MPA failure rates of up to 80% (Dharmaratne, Yee Sang et al. 2000). MPA in French-speaking countries are little studied by comparison, particularly in the Indian and Pacific Oceans, and a global survey of dive operators concludes they present little potential for revenue generation (Depondt and Green 2006). This was variously linked by Depondt et al to low visitation rates by divers, a lack of fee structures or low fee rates and in places a perceived lack of difference between MPA and areas outside. In Africa, there are reported to be no revenue raising systems in place in Madagascar, Mauritius or Reunion. This focal study investigates limitations to funding in an African French-speaking island of the south-western Indian Ocean with newly announced MPA. It sets out to:

- Determine tourists' WTP for environmental goods and services provided by Marine Protected Areas (WTP-MPA) and Marine and Coastal Protected Area (WTP-McPA) in a French/Creole-speaking Indian Ocean island.
- Profile visiting tourists and their perceptions to clarify tourist traits which may influence Willingness to Pay (WTP) at early McPA planning stages.
- Interview a wide range of stakeholders to conclude with the implications of tourists' perceptions and WTP for McPA policies aimed at ecosystem-based sustainable development in a regional island reef context.

Willingness to pay is from here onwards mostly denoted either by WTP-McPA, for an unspecified MPA project with a notable coastal land element*, or WTP-MPA for a similar marine area discussed without reference to any land element.

2.7 Research site

French-speaking (Creole) Rodrigues is a remote, semi-autonomous region (104 sq km) of Mauritius typifying the environmental and development problems faced by small islands (Armstrong 2003). The little-known island (18.3 km long by 6.5 km wide) lies at 19°4'S, 63°25'E in the inter-tropical zone of the south-western Indian Ocean around 600 kms east of Mauritius, from which it gained semi-autonomy in 2003. The mountainous island's badly eroded, deforested and bench-terraced flanks rise to almost 400m (McDougall, Upton et al. 1965) from the Indian Ocean's largest reef lagoon, whose area (240 sq km) is double that of the land, allowing extensive traditional fishing activities and scope for marine tourism on either side of the 90 km fringing reef.

2.7.1. Fishery pressure

Rodrigues population (38,000) has roughly doubled every 30 years from nearly 10,000 in the 1930s (density 354 sq km). The island has been left behind in wider Mauritius' rapid rise to middle-income status (UNDP 2003; KPMG 2006). High birth rates, school failure, social problems, and unemployment are notable. Many youngsters turn to fishing in the lagoon or migrate to Mauritius, where there is an equal-sized Rodriguan population. The island's reef ecosystem is damaged by fishing and lagoon sedimentation, with other threats from agricultural chemicals and sewage. An estimated 40% of coral is impacted (Anon. 1999; KPMG 2006). Fish exports underpinning Rodrigues' food supply and livelihood are now negligible (CSO 2005),

prompting concern among fishermen, scientists and policy-makers over the state of the fishery and efforts to find alternative incomes for fishers.

2.7.2. Small island tourism in Rodrigues

Tourism started with new air links in the 1970s after independence (UK) but it did not expand much until the late 1990s and remains limited by poor air access (KPMG 2006). Tourism is basic, led by three middle-ranking hotels with in-house marine sports facilities offering diving (no decompression chamber), kite surfing and small boat excursions to islets. Branding itself as “authentic” and “ecological”, Rodrigues drew a record 64,000 visitors in 2004 but seeks a greater niche in regional tourism. Mauritius’ regional English-speaking counterpart, Seychelles, already has considerable revenue from a 100,000 per annum tourism base now targeted for much smaller Rodrigues by 2015. However, further tourism expansion could be detrimental: “Rodrigues may become as heavily developed as some areas of Mauritius if an integrated approach is not taken to managing the marine and coastal environment”(UNDP 2003). Mauritius (pop. 1.2m), the access portal to Rodrigues, aims to double its tourist numbers to two million, based on its more luxury beach-hotel tourism image with mass-market appeal to Europeans led by France (40% in 2004 inc. Reunion island). Rodrigues is particularly dependent on French tourists, who accounted for 85% of foreign arrivals in Rodrigues in 2004, or 25% overall (including local and non-tourist traffic) (CSO 2004).

2.7.3. Biodiversity and nature tourism

The importance of biodiversity to sustainable development based on tourism is increasingly recognised in Mauritius (Sobhee 2006) as its Lomé preferential trade terms covering traditional sugar and textile exports to the EU end by 2010. Rodrigues participated in neither sector and remains poor and severely degraded since settlement in the 1700s (North-Coombes 1971; Oliver and Lynch 2004). However, its remaining

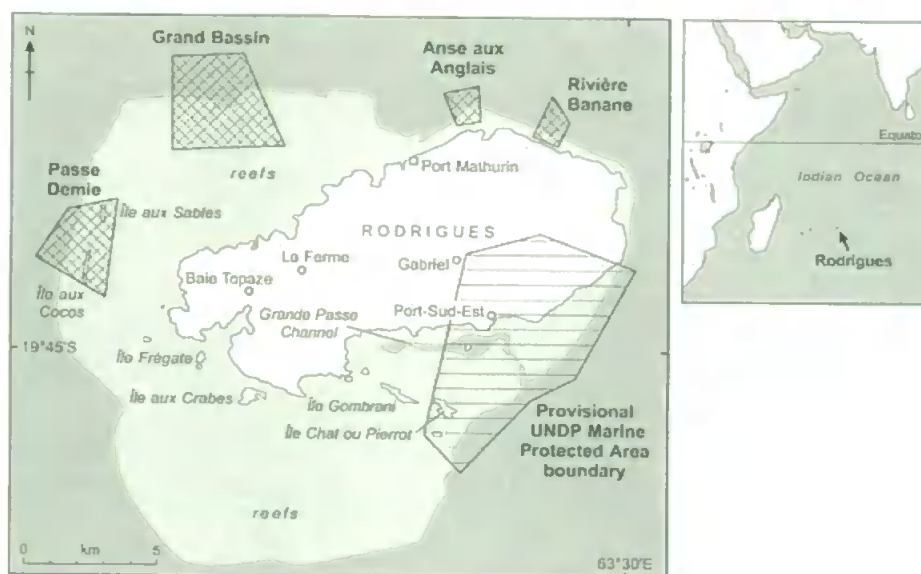
endemic and unusual land animals and plants (Strahm 1989) are increasingly protected in land reserves (7.5% of land area). Despite extensive damage to coral in the region Rodrigues also has some of the most pristine stands, along with fish diversity of interest to divers (Gell, Lynch et al. 2003). The diving sector is little developed. A possible 1,500 SCUBA divers use the lagoon annually at a rate of 1 or two dives a week, excluding snorkeller numbers reported by local tour operators to be far higher.

2.7.4. Marine reserves and Marine Protected Areas

Proposals for MPA in Mauritius (Robertson 1974) pre-date the main island's massive coastal modifications for beach tourism. With environmental problems now apparent MPA are receiving more attention. Two MPA have been declared on the main island. Blue Bay (353 ha) and BalACLava (485 ha) were established in 1997 but so far they have suffered from high administrative and enforcement costs. Compliance with regulations by fishers has tended to be poor, which is reported as a reason for diver operators there not using them due to a lack of difference between protected and non-protected areas (Depondt and Green 2006).

Rodrigues began substantive work on a Marine and Coastal Protected Area (UNDP-Mourouk Project no. MAR/03/G35/A/1G/99) shortly after this study in 2005/06 and later gazetted four MPA (marine reserves) in the north (2007) as proposed by a local NGO before regional autonomy (Gell, Lynch et al. 2003; UNDP 2006) (Figure 4). Both projects contain socio-economic development goals beyond biodiversity protection and fishery enhancement, with the McPA clearly committed to participatory management aimed at sustainable development. Details on both projects during the survey were largely limited to boundary outlines, which in the case of the McPA remain subject to change.

Figure 4: Map of Rodrigues showing its lagoon fishery (light grey 'reefs'), sites of four marine reserves (north) declared in 2007, and a new multi-use Marine and Coastal Protected Area (south-east) as proposed for UNDP-GEF funding



Rodrigues is a good study site for determining how tourists perceive remote islands as tourism destinations, and whether they can or should financially contribute to the costs biodiversity conservation management, which remains poor (Anon. 2005).

The South Mascarene region ranks highly in terms of existence but also threats to marine endemism (Roberts 2002). Tourism adds to over-fishing and pressure on the environment (KPMG 2006). Mauritian fishers are marginalised (Hollup 2000). More specifically, Rodrigues is an economic burden to Mauritius (Anon. 2005) and the McPA is expected to contribute to its own budget. Entry fees were highlighted in project documents for both the McPA and MPA, with marine tourism, and in particular diving, identified as good potential sources. The McPA was originally conceived with a substantial reef-to-hilltop land element for which funding remained in doubt during this study. Rodrigues' main McPA at Mourouk is expected to serve as a role model for improving Mauritius' other MPA.

3. METHODOLOGY

Survey and interview design and conduct were based upon quantitative and qualitative research guidelines for coral reef management in Bunce, Townsley et al. (2000). Recorded semi-structured interviews (SSI) with tourism operators (12), NGOs (6), fishers (9) and government officials (15) were followed by a purposive random survey of 351 tourists by the lead author. SSI respondents were questioned about their perceptions of the extent and causes of island degradation, trends in tourism, the prospects for MPA-based tourism as a basis for sustainable development, and potential obstacles to MPA success. Responses helped guide survey question formulation, while providing qualitative context to tourists' subsequent survey answers and a basis for comparing all stakeholders' perceptions of proposed MPA and entry fees. A mixture of quantitative and qualitative research approaches are recommended (Bunce, Townsley et al. 2000) for coral reef management contexts and social research in Africa (Bulmer and Warwick 1993). Such mixed approaches can reduce subjectivity and have long been recommended when statistical findings are hard to interpret outside of a qualitative framework (Light and Pillemer 1982).

Tourists in the survey were asked closed and open questions* on a face-to-face and self-completion basis as needed. Surveys written and conducted in French were completed mainly in the short December 2005-January austral summer high season (44%), but extended through February (Mauritian Valentine's Day promotions) to the end of May 2006 (28%) to pick up intra-annual variance, including the other main peak arrival period for all tourists in April (28% in 2004). English language surveys were used for the minority of non-French speakers. Security clearance allowed 81% of surveys to be conducted by the lead author in the departure lounge of Rodrigues' airport after poor results at piloting stages of self-fill surveys left at hotels and other key locations.

3.1 *Survey

Tourists indicated trip details including length of stay, return rates or intentions, accommodation and eating habits. They also gave socioeconomic data on age, sex, household income, education and employment status. Tourists were asked to state their residency instead of nationality, to identify tourism patterns that could otherwise be hidden. The south-western Indian Ocean (SWIO) region includes French Overseas Territories and Departments (DOM-TOM), such as Reunion (DOM), whose resident French nationals' socioeconomic characteristics differ from mainland France. Respondents then ranked from 1-5 in declining order of importance up to five visit motives from a list established in pilot interviews with tourists, tourism operators, government stakeholders and secondary data.

Contingent valuation was used to determine WTP (Garrod and Willis 1999). All tourists were asked (Box 3) an open ended choice question (1) relating to entry fees to use a

Box 3: Contingent valuation survey questions eliciting 351 tourists' WTP to use two generalised forms of island marine (and coastal) protected areas in Rodrigues

Question 1 (WTP-McPA)

a) The health of the environment on land and sea is linked. Should Rodrigues set up a Land and Sea Park to protect its environment, with clearly defined zones for sport, leisure, fishing and conservation?
(All users would pay an entry fee and benefit from a stronger and visibly improved natural environment)

YES/NO

b) (If 'Yes') State the amount that you would be prepared to pay **PER ADULT/PER WEEK** for an entry pass giving access to such a land and sea park. *(Be honest - take into account your financial resources and ability to pay if asked)*

Total amount per week/per adult: (36 Rupees =1 Euro)

Question 2 (WTP-MPA)

Let's say divers and snorkellers are required to contribute to a fund dedicated to the protection of fish, coral and tortoises.

a) In principle, would you be prepared to pay a sum of money on top of all your other diving costs for the protection of the marine environment in Rodrigues? *(Divers would benefit from more abundant fish and coral. The neighbouring degraded fishery would recover)*

YES/NO

b) (If 'Yes') Indicate the extra amount, **PER PERSON/ PER DAY**, that you would be prepared to pay for access to the Reserve or Park, where fishing would be banned.

1 euro	7 euro	More than 20 euro
3 euro	10 euro	Other (specify)
5 euro	10-20 euro	

Marine and Coastal Protected Area, with a zoned land element. Divers and snorkellers then answered a dichotomous choice question (2) relating specifically to WTP to use an MPA. Question formats were selected from a range available (Garrod and Willis 1999; NOAA 2005). Open-ended questions appeared most likely to reflect a respondents' true, if not conservative, WTP-McPA value (Bateman, Langford et al. 1995). Dichotomous choice questions, used for the MPA with a scale derived from pilot study answers, allowed elicitation of a more optimistic upper range specific to divers. Question 2 uses a payment card format common in published studies of diver fees (Arin and Kramer 2002).

Tourists were asked to rate the environmental state of Rodrigues on a five-point Likert scale to see if their general impressions influenced WTP to enter either kind of proposed park. Likert scales are common in economic evaluations (Garrod and Willis 1999) and social research, including MPA contexts. Lagoon recreational users gave a rating of their overall experience, stating whether they had visited other similar, and perhaps comparable, tropical destinations. Divers were asked for a specific rating of coral state on a more sensitive 7-point Likert scale. Coral state is a good indicator of large-scale ecological impacts of development on tropical island systems (Sealey 2004). Tourists gave open-answer reasons for and against WTP at the survey's end, summarising their qualitative pre-and post-trip impressions of Rodrigues, and how it could improve its attractiveness to tourists.

3.2 Sampling

The main survey sample (n=351) was based on official air passenger arrivals statistics for Rodrigues (CSO 2005) showing 45,433 air passengers (including Mauritians but excluding Rodriguans) visiting in 2004, the peak year for all arrivals (including local, boat and non-tourist traffic). A sample of this size is recommended in coral reef management contexts (Bunce, Townsley et al. 2000) for a statistically significant

survey (95% CI) of a stakeholder population size of 50,000. Visitor statistics show a sporadic but continual rise from around 6,000 visitors in 1982 to 25,000 in the mid-1990s. Visits then expanded rapidly to a record 60,892 in 2004 (CSO 2004) before falling by 23% to 46,800 during the survey (2005). Qualitative surveys with other stakeholders were completed using "snowballing" interview techniques to identify power-brokers, decision-makers and those likely to be impacted by MPA, whether in fisheries or tourism sectors (Bunce, Townsley et al. 2000).

3.3 Data analysis

351 usable returns were obtained with 100% response rates for critical questions on WTP. Respondents had up to an hour spare for completing surveys between arrival and departure from the airport and were assisted throughout on a face-to-face and/or self-fill basis as needed. Survey responses were correlated to determine factors affecting WTP, using a variety of non-parametric tests available in SPSS social science software packages (Kruskall-Wallis, Mann-Whitney U, Spearman's rho) according to specific question and answer formats. To reduce strategic bias (Garrod and Willis 1999) open-choice WTP-McPA answers were scaled to remove distorting outlying values. This allowed direct comparison between WTP-MPA and McPA. Qualitative responses were explored for contextual clarifications and range rather than statistical relevance and explored for important issues not probed in the survey.

4. RESULTS

4.1 Tourist profile

4.1.1 Socioeconomic factors

In the survey, visits by residents of France (31.9%) and its integral overseas Department of Reunion (29.9%) predominated compared to 'Other' foreigners (15.4%)

and Mauritians (22.8%). Tourists came mainly as couples (45%), including Mauritians on seasonal 'romance' hotel packages (February), while the remainder were almost equally split between singles, families and groups. Most were salaried employees (50%), self-employed (26%) or retired (13%) with incomes typically lower for Mauritian and Reunion residents, who together accounted for the majority of the third of people overall in the lowest income bracket (<25,000 euro). Median stated income was 25-50,000 euros when excluding 20% declining to declare ($SD \pm 0.994$). Visitors were highly educated or qualified in line with university enrolment rates in France generally and an education-focus in Mauritius, with only 43.3% not holding a degree or postgraduate degree (or professional equivalent). Visitor ages fell equally (27%) into three groups (25-35, 35-45, 45-60), with only 6% under 25 and 10% over 60. Males (55%) exceeded females. All visitors ate fish or octopus, with 92% consuming up to 2 such meals/day, creating a continual pressure on the fishery.

4.1.2 Visit patterns

Foreign visitors surveyed largely outstayed Mauritians. Compared to the median visit of 5-6 days Mauritians took shorter and more frequent breaks eased by proximity and direct flights, whereas incoming visitors mostly made obligatory, unreliable flight connections in Mauritius. Repeat visit rates of 31% fall to 27% when excluding Mauritians. This suggests little destination loyalty, particularly as Rodrigues was the main destination of most tourists' holiday (64%, or 40% when excluding Reunion), compared to 24% citing Mauritius. Better marketed Mauritius has a luxury brand of beach tourism at variance with reality in poorer and geographically different Rodrigues. Most tourists (54%) used hotels, mostly owned by outsiders. Rodriguan tourism providers seeing little personal benefit in Mauritian-style luxury hotels provide the next most popular option of gîtes, based on French rustic tourism models emphasising local ownership. Hotels are more standardised and marketed than local accommodation.

Table 11: Variation in tourist motives for visiting Rodrigues (ranked high =1 to 5 = low) by country of residence (bracketed columns show standard deviation)

Visit motive (Top 3 in bold)*	Country of residence*							
	Mean rank (1=high-lowest=6, mid-point=3.5) and (SD+/-)							
	%	Mauritius	Reunion	France	Other			
Land or marine sport	52	5.01 (1.69)	3.75* (2.12)	4.19 (1.93)	4.13* (1.96)			
Natural beauty	77	3.56* (1.9)	2.88* (1.68)	3.11* (1.94)	3.5* (1.98)			
Creole people, culture	60	4.46 (1.7)1	4.16 (1.61)	4.17 (1.8)	4.52 (1.63)			
Remoteness, calm, security	62	3.9* (1.8)	4.26 (1.78)	3.89* (1.72)	4.5 (1.7)			
Sun, sea, sand	60	4.9 (1.65)	3.82* (1.74)	3.7* (1.97)	3.86* (2.12)			
Romance	17	5.14 (1.62)	5.49 (1.39)	5.63 (1.15)	5.46 (1.27)			
Curiosity/Novelty	38	4.98 (1.69)	4.59 (1.94)	4.78 (1.76)	4.89 (1.8)			
Business and social	19	3.81* (2.38)	5.75 (1.05)	5.76 (1.03)	5.01 (1.85)			
Endemic flora and fauna	24	5.56 (1.1)	5.38 (1.21)	5.38 (1.20)	5.31 (1.38)			

4.1.3 Visit motivation

Natural beauty was the highest* motivation (Likert 1*-5) for visiting Rodrigues, both overall and for each category of visitors. All foreign visitors then chose sun, sea and sand associated with traditional beach holidays, followed by outdoor sports, except for French residents who preferred remoteness and calm (Table 11). Mauritian residents were mostly likely to visit for business and social reasons.

Visitors from France and Reunion stated visit motivations suggesting a higher affinity for Rodrigues' people and culture than other visitors. The desirability of a sea and coast environment for all visitors (90%) was rated highest by long-haul visitors from France and Other countries (79%), and was also higher for regional visitors from Reunion island (66%) compared mainland Mauritians (40%).

4.1.4. Perceptions of environment

The general environmental state of Rodrigues on land and sea was ranked highest by visitors from 'Other' countries, ahead of (in order) Mauritius, Reunion and lastly France. The overall ranking was 'Good' ($n=351$, Median and modal value of '2' on 1-6 Likert scale, $SD+/-=0.9613$). The lagoon was similarly rated by each group visiting ($n=247$, $SD+/-=0.920$). However, opinions of coral state among the 153 divers ($n=167$) who felt able to give a rank were more varied and uncertain, with residents of France and

Reunion giving lower ratings than "Others" and Mauritians (*Overall median and modal value '3', or 'Quite Good', on 1-7 Likert scale with 7 = 'Dead', SD+/-=1.29*).

4.1.5. Lagoon activity

Nearly all lagoon visitors and divers (78%) had visited (or lived in) other tropical destinations, providing varying bases for comparison with Rodrigues. Of those that had been out in Rodrigues' lagoon, most had been '*in the water*' to swim, snorkel or dive (274, or 62%), or '*on the water*' for board and boat sports (71, or 20%). A majority of tourists had taken a formal boat excursion (62%), including glass-bottomed craft or else accompanied fishers by foot or boat (30%). This involves some tourists in reef destruction by walking over it and in some cases octopus fishing with bars. Female octopus fishers are unusual and attract a lot of media coverage despite local political concerns of the extent of their damage to the reef.

4.2 WTP to use Marine and Coastal Protected Areas and Marine Protected Areas

351 tourists were surveyed, of which 79% stated WTP (>0 euro) for the mixed Marine and Coastal Protected Area. 78% (274) of all respondents had participated in some form of lagoon sport or excursion. Of these, 61% dived (167); meaning divers comprised a minority of all surveyed visitors (47.6%). Divers stating WTP-MPA (>0) accounted for an even smaller minority of 32%. A lower percentage (67%) of divers stated WTP (daily fee) to use an MPA (>0 euro) than all tourists' WTP a one-off weekly fee giving access to MPA and land zones of a larger Marine and Coastal Protected Area (Appendix 7 and 8).

Tourists (351) were willing to pay 7 euros (median, mean =6.2, SD+/-=2.5679) for weekly entry to a McPA zoned for fishing and leisure activities (WTP-McPA). Divers were WTP a daily fee of 3 euros (mean and median, SD+/-=1.8287) to use an MPA,

Figure 12: Correlation of divers' (n=167) WTP-MPA and WTP-McPA (Spearman's rho test =0.684, p<0.001). Bars show range, dots show mean (95% CI).

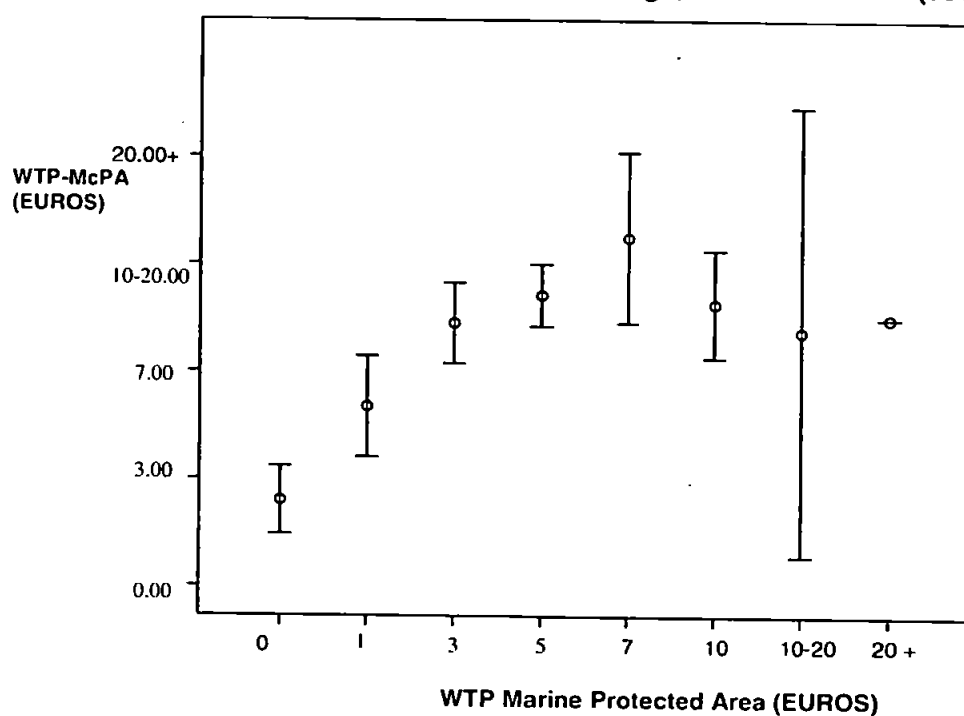
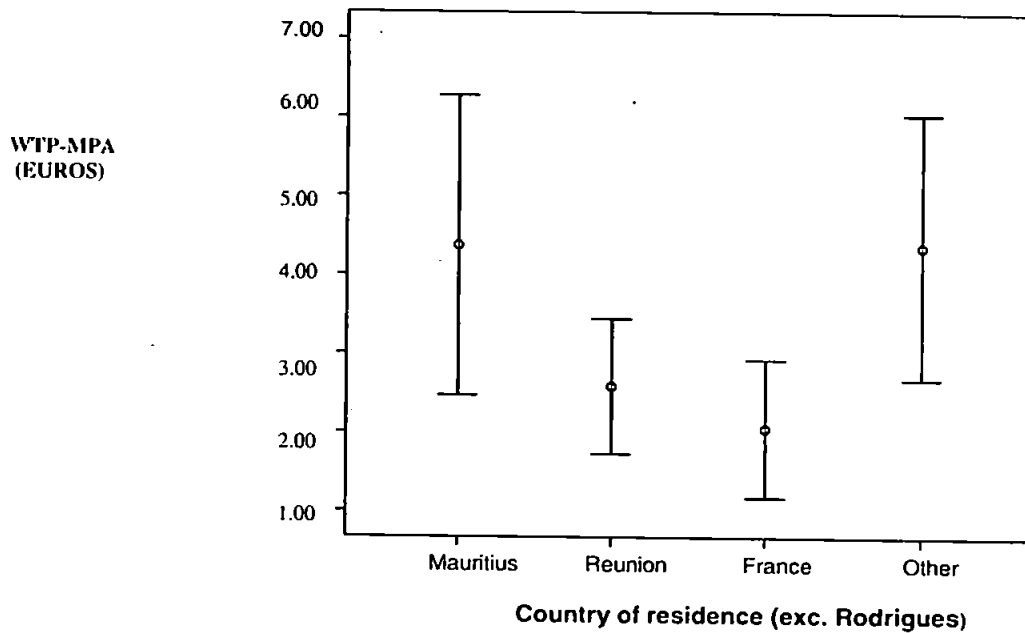


Table 12: Socioeconomic factors correlating strongly with tourists' WTP compared to visit motives or perceptions of environmental state (for McPA and/or MPA entry)

Factor influencing WTP (95% CI or Chi value)	Test	N	WTP McPA	WTP MPA
<i>selected n.s. p values (95%) bracketed</i>				
WTP MPA	***	167	0.00	-
Residence	*	351	0.029 Chi=9.032	0.018 Chi=10.112
Age	***	314	n.s. (0.571)	0.046
Education	**	351	n.s. (0.42)	n.s. (.988)
Household income	***	351	0.001	n.s. (0.169)
Accommodation type	*	351	n.s. (0.414)	0.027 Chi=9.216
Visit length (days)	***	351	0.031	n.s. (-0.357)
Number of visits	***	351	n.s. (0.354)	n.s. (0.700)
Return visits possible	*	351	n.s. (0.544)	0.014 Chi=10.627
Rodrigues main destination	*	351	n.s. (0.616)	n.s. (0.079)
Prefers development	**	304	n.s. (0.795)	n.s. (0.151)
Trip motive				
Business or social	***	351	n.s. (0.788)	0.007*
Endemic flora and fauna	***	351	n.s. (0.451)	0.014
Curiosity, novelty value	***	351	n.s. (0.481)	0.042
Remoteness, calm, safe	***	351	n.s. (0.464)	n.s. (0.094)
Lagoon sport or excursion	**	351	n.s. (0.192)	n.s. (0.090)
Diver or non-diver	**	351	n.s. (0.252)	n.a.
Environmental rating				
Rodrigues island (land-sea)	***	351	n.s.	n.s.
Lagoon rating general	***	250	n.s.	n.s.
Coral state	***	153	n.a.	n.s. (divers only)
Visited other tropical seas	**	274	n.s.	n.s.

Kruskal-Wallis test Mann-Whitney test** Spearman's rho correlation***

Figure 13: Relationship between WTP-MPA and residency, showing lowest WTP among residents of France and Reunion. Bars show range, dots show mean (95% CI)



suggesting a similar or greater weekly per capita fee-generating potential if divers use an MPA on two days or more per week (WTP-MPA). WTP-McPA was not statistically higher (95% CI) among divers (167) than non-divers (Mann-Whitney test, $p=0.252$).

However, divers' WTP for MPA and McPA on the other hand were closely correlated ($N=167$) with both rising (Figure 12) to a point where divers pay 7 euros/day to use the Marine Park, after which their WTP-McPA falls to earlier levels. Results suggest scope for a mixed fee regime (possibly at island entry level), but also that divers are prepared to pay higher levels for MPA amenity than more general fee payers who may not dive under a mixed fee regime.

4.2.1 WTP (Residency)

WTP-McPA and particularly WTP-MPA correlated most strongly with country of residency (Table 12). WTP on both counts was highest among the minority of visitors from "Other" countries (Figure 13) compared to the majority of visitors from France and

Table 13: Diving participation rates showing high fee potential from countries 'Other' than those currently dominating diving tourism (French-speaking countries)

		<i>Visitors</i>		<i>% Diving</i> N=167	<i>Rank</i>
		N=351	%		
<i>Residence</i>	<i>Other</i>	54	15.4	46.3	1
	<i>Reunion</i>	105	29.9	60.1	2
	<i>France</i>	112	31.9	54.5	3
	<i>Mauritius</i>	80	22.8	24.5	4

Reunion. Mauritians', who dive least, stated high WTP-MPA but low WTP-McPA, which they are more likely to be asked to pay. The minority of visitors from 'Other' countries also dived the most frequently (Table 13), as well as stating the highest WTP-MPA, presenting perhaps the best per capita potential for fee generation.

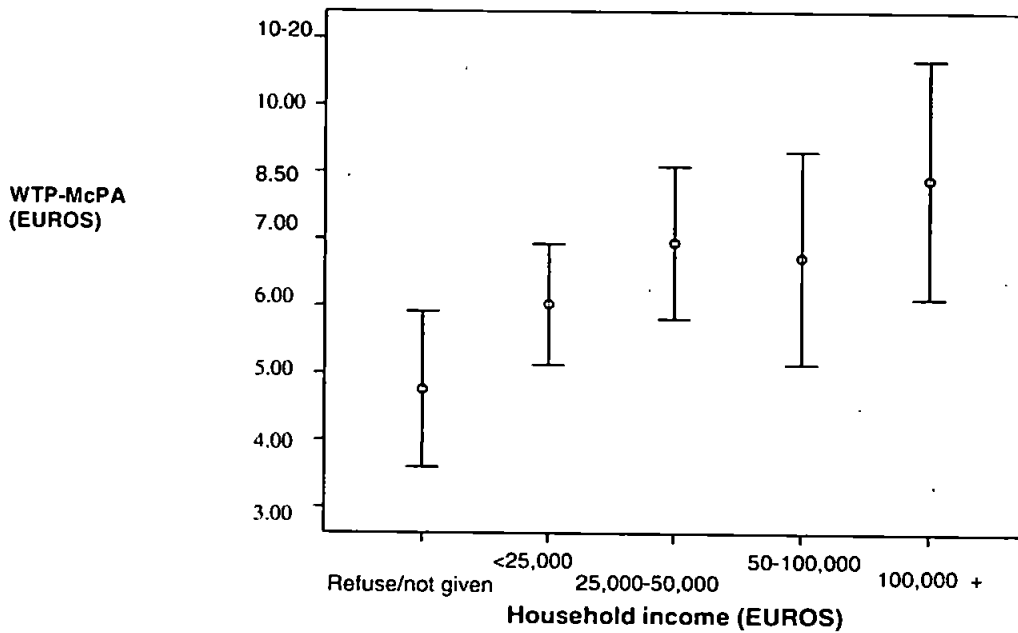
Apart from residency, no other single factor determined WTP for both parks at the same time to a high statistical level (95% CI), but other variables determined WTP in separate instances and others were significant at lower confidence intervals.

4.2.2. WTP (Income)

Income (Table 12 above, Figure 14 below), regardless of age, was the second single most significant determinant of WTP for the McPA alone but only when including the lowest WTP bracket stated by a group not revealing their income. WTP-MPA was not determined by income, although highest among high earners (100,000+ euros).

People's income rose with age (Spearman's rho test =0.147, $p < 0.01$) but their WTP-MPA statistically declined with age (excluding the minority over 60). Over 60s earned less but WTP-MPA (not McPA) was higher, perhaps due to reduced responsibilities.

Figure 14: Relationship between WTP-McPA and income (when including low WTP among non-declarers of income. Bars show range, dots mean (95% CI))



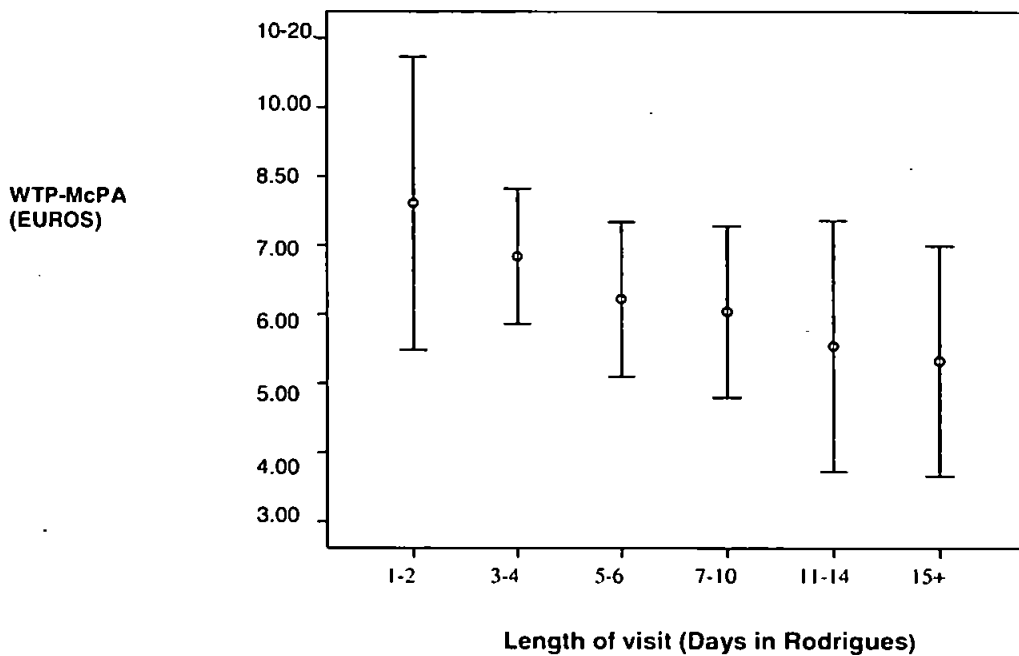
4.2.3. WTP (Endemics)

Divers' WTP-MPA rose in line with a high interest in endemic biota, providing a biodiversity conservation incentive for either marine and/or land park managers.

4.4.4. WTP (Trip satisfaction)

Overall trip satisfaction appeared to partly determine WTP as tourists who would consider returning stated the highest WTP-MPA. WTP levels among such visitors ranged within a more certain, narrower band compared to others with less clear intentions ("Maybe"). Scope for raising McPA fees appeared to be highest in the first week (Figure 15). Divers tended to stay longer than other tourists and their WTP-MPA appeared to be more durable over longer trips than WTP-McPA.

Figure 15: Relationship between WTP-McPA and visit duration, showing reduced WTP potential for longer visits. Bars show range, dots mean (95% CI)



4.4.5. WTP (Environmental state)

Although 'natural beauty' was ranked highest as a visit motive among non-Mauritians, their rankings of the environment did not statistically determine WTP to a high level (95% CI), suggesting WTP may be unresponsive to environmental improvements. Although 90% of respondents of lagoon users had visited other tropical destinations (n=274) this scope for comparison did not statistically affect WTP for either kind of park proposed. French visitors stating the lowest WTP also rated coral health lowest (*Spearman's rho* = 0.586, *p* = 0.073).

4.5.6. WTP (Other factors)

Casual and curious visitors with less specific preference for activity stated low WTP-MPA (WTP inversely correlated to high novelty motives). The correlation between accommodation type and WTP-Park appears to be related only to a small minority

using small local alternative lodgings to hotels (10%, mainly Mauritian and French-speaking).

Diver operator: "It costs a lot to come to Rodrigues. (Reunion) people look for cheap accommodation so they have money to dive or the rest of the holiday in Rodrigues"

Other tourist factors were not highly correlated with WTP (CI 95%). Even so, WTP-McPA was linked (90% CI) to participation in boat and board sports (Kruskal-Wallis test, $p=0.09$). WTP-MPA was loosely linked to lagoon sports and excursions generally. Widespread tourist concern over development (67%) of the wild east coast featured in most tourist literature did not appear to affect WTP, nor did UNESCO World Heritage status mooted for the Mourouk McPA in project documents.

4.3 Stakeholders' qualitative perceptions

Overall, socioeconomic characteristics of visitors appeared to be the strongest indicators of WTP based on quantitative surveys. However, visitors' qualitative perceptions suggested a wider range of interrelated factors may be influential.

4.3.1. Tourists' conceptions of Rodrigues

Tourists' pre-trip images of Rodrigues suggest scope for easy disappointment and low return rates. Pre-trip images were general, escapist and not closely linked to sports activities likely to generate most entry fees. Experienced and highly educated diving tourists were among those surprised by the island upon arrival:

"It was dry. That was the first impression ... and just how many people there are here. It is definitely not a deserted tropical island. We did not quite expect it."

A marketing consultant likewise expressed surprise at his high-level tourism industry brief from France, Rodrigues main foreign tourism partner:

"Rodrigues is very little known ... (the director) said to me 'I want a tropical post card. Make people want to come here!'. That's what they (directors) expect – it's an island in the Indian Ocean so it has to be 'lagoon', 'blue', and 'turquoise'. But (we) are not going to tell it like that, because it is not a beach destination."

Although some tourists had no pre-trip images at all, others expected more of a 'Robinson Crusoe' and 'Eden' paradise experience at variance for some people with the largely deforested, semi-developed and only sub-tropical realities of the cyclone-swept island. Poor marketing was often mentioned but tourists' views were also related to images of the region more in line with French European romantic literature (Grove 1995; Prosper and Tranquille 2000). Rodrigues still reminded local and regional tourists of a nostalgic pre-development era lost in their own degraded islands, while tourists generally liked Rodrigues' non-commercial atmosphere, albeit at the risk of boredom.

Diving tourist: *"It's quite different from Mauritius. The culture's different, the people laid back, friendly and there are not so many tourists. In Mauritius, since there are more tourists, they (Mauritians) are more for the principle 'Cash is King'. That is the difference, but it may change in Rodrigues."*

Politician: *"We want to develop Rodrigues differently. In Mauritius they have problems ... mass tourism with big concrete buildings. We do not want that."*

Tourists' end-of-trip impressions veered away from "wild" and "primitive" towards less dramatic "calm", "tranquillity" "nature", "landscape", "lagoon" and "beauty" and "friendly". Respondents mostly referred to what they saw rather than what they did. Negative comments were rare, but tourists suggested many steps for Rodrigues to attract tourists in future. Most opposed Mauritius-style development (less so among divers) while still suggesting a need for better marketing, connections, infrastructure, sports/activities and cleanliness. Many were offended by litter blowing around the island and tourists often referred to it when talking about the environment and WTP.

Overall, tourists left with different impressions of Rodrigues generally suggesting that Rodrigues' lagoon and landscape is highly marketable to tourists as an opportunity for observation of nature in a calm ambiance still mixed for some departing visitors with European idylls of palm-fringed desert islands with friendly local people. The desire for

"unusual" Rodrigues to "stay as it is" was common. Tourists' concerns over the risk of tourism exceeding island carrying capacity was at times sophisticated, with many bequest motives mixed into reasons for WTP.

4.3.2. Tourists' perceptions of McPA fee regimes

285 of the 351 tourists surveyed gave qualitative reasons for or against entry fees, which were explored for their range rather than statistical significance. Visitors were split between those seeing Rodrigues as architects of their own environmental downfall needing to be 'educated' and 'more responsible', preferably without external help (Table 14). Others saw clear environmental risks in tourism and a need for partnership with Rodrigues to achieve varying notions of "sustainable" development. efforts elsewhere, including Africa, where conservation has historical overtones of colonialism (Grove 1990; Adams and Hulme 2002):

Female diver and kite-surfer: "If we can see it being managed as a reserve - I am not saying if we can see benefits directly to us - then we will probably pay ...five euros max - on top of the dive. If we are paying any amount and doing the kind of dive that we did today without seeing anything then no way.

Male diver and kite-surfer: Yes. A tax of five euros on the sport that we did, be it the kite boarding or the diving or whatever. ...It (MPA) needs to be (managed) by a committee with the guys that live here. Otherwise it is a waste of time. If you look at a lot of the game parks we have got now (Africa) they say "you have got the tribe, and they still live there and they contribute to the running and the day-to-day operations". Africa does not have too many success stories of making that happen. The benefits normally have to be purely financial.

Respondents' qualitative comments suggested Rodrigues' seas compare favourably with other destinations. Favourable comparisons extended to Rodrigues' marine life:

South African male diver: "Big fish don't mean a lot to me because I grew up on next to a reef (fish there are much bigger...get many more of them) so we tend to go looking for coral. On that aspect, well, it's OK, better than Tonga, worse than Belize"

French female diver: "The coral reefs, the diving is very good here too (compared to Mauritius) because the divers are not so dense when you go out ... fish are not afraid of you. I think the underwater world is better than in Mauritius, it is still intact."

4.3.3. *Tourism operators' perceptions of McPA*

Local stakeholders' qualitative comments raised other issues over McPA that could affect local compliance with protected area rules and negatively impact tourists'

Table 14: Generalised statements of tourists' reasons for and against WTP to enter Marine and Coastal Protected Areas and/or Marine Protected Areas

Not WTP	WTP
Tourists as Cash Cows, sick of parks, free for all	Tourists can and should pay as a duty of a principle/ equal beneficiaries of conservation
Too many taxes on tourists already	
Government and tourist sector should be responsible, not tourists	Local people and government lack funds and tourists can easily afford to help.
Funds exist already or are available elsewhere	Funds conservation, education and management
Funding is not the main issue. Other issues need to be tackled first. A marine park is not needed.	Creation of visitor attractions, encourages (repeat/longer) tourists visits, better service, jobs
Corruption and management issues mean fees are a waste of time.	Promotes conservation and development, use of zoning beneficial, restock the sea, keep natural
Polluter pays – I can see them walking on the reef	Positive ecological and tourism impacts of MPAs
Education and local responsibility, not fees	Influences overall style of tourism development

perceptions of amenity value and WTP. Tourism and diver operators agreed over the need for McPA but doubted the willingness of tourists to meet their WTP if asked.

***Tour operator:** In Europe, people are conscious about the environment. Each diving client is already obliged to pay a little for insurance so why not for the environment?*

***Sports manager:** Psychologically, people do not (want to feel) squeezed dry*

***Tour operator:** Maurilians come as they are in their own country they are trying to spend the less possible ...they know the language (how to get about, eat ...).*

Tourism sector operators saw a role for park entry fees but some feared external climate stressors and failure to control land development could undermine benefits of protected areas, perhaps reducing WTP or causing tour operators to avoid McPA.

***Hotelier:** More people...would give us more money to run the park ...(and) work*

***Hotelier:** (Tourists) coming to dive would get more (fish)...(need to) protect the sea*

***Dive sector:** Reserves would ... protect marine flora and fauna, coral will regenerate,*

***Diver sector:** There is no funding for working on the land. So, you can spend lots on money working on the McPA...(but) the problem of the sea comes from the land ...*

***Dive sector:** Diving can be good... but not as it is. You can't have people saying 'we will ask divers to finance it' and when they come they are not happy about their dive.*

***Tourism investor:** Certain areas ...hit by bleaching, others (fantastic)...if the (rough) sea allows you (out of the lagoon) there are great spots.*

Table 15: Fishers' (n=93) perceptions of benefits of MPA-related tourism (%)

Survey questions to fishers	Y	N	?
Does Rodrigues need more fisheries reserves or marine parks?	87	13	-
Do tourists at sea (inc diving) disturb fishing activities?	54	45	1
Would it bother you if tourists were allowed to dive or snorkel in reserves or parks where your fishing is partly or completely banned?	58	42	-
Could marine tourism benefit fishers in any way?	65	32	3
Would there be enough fresh fish for Rodriguans if tourism expands?	56*	43	1
Are existing marine reserves enforced?	38	55	7

*68% stated yes only if fishing was extended beyond the lagoon to exploit new fishing grounds

4.3.4. Fishers' support for McPA tourism

Fishers in principle support McPA subject to considerable doubts over jobs, income, and related enforcement issues which could undermine their compliance and also result in a lack of perceivably higher tourism amenity as reported in Mauritius (Table 15).

Fisher: No rain. No work. That is a big problem – cyclones, droughts. What can we do? There are too many looking for work, so they take to the sea.

Fisher: Tourists may not come one day... We need to exploit what we have already.

Fisher: The fish would come back...good for tourists... to dive...like the Seychelles.

Fisher: The fish know the zones where they are targeted...which are fished. If the fishermen go there they will not. Sharks, tortoises go to those places.

Tourism operators saw limited scope for McPA to create employment for fishers:

Hotel investor: A fishermen is at the level of working in the boathouse, err, it won't create million jobs in my opinion but it will relieve a bit of the pressure

Travel agent:... (fishers are) funny, talk loudly, comments on everything, discuss ... I don't think a tourist would like to see this by the pool...find other options in the sea...

Fishers saw potential for guiding tourists around the lagoon but a large minority saw diving and kite-surfing as detrimental. Fishers expected limited alternative income from farming, even in the McPA due to deforestation, erosion, falling yields and prices, limited markets and poor enforcement of land rules due to uncertain tenure. The McPA is aimed partly at addressing some of these long-standing land issues.

4.3.5. Conservation and development conflict

Political will was seen as a main determinant of McPA success by planners forecasting limited immediate job creation and a need for long strategies to take fishers off the sea. Rodriguan politicians support McPA but understand the short-term conflict of conservation and development at early stages of McPA development. In the absence of immediate jobs, fishers' demand financial compensation, which in Rodrigues means state funds increasingly managed by local politicians. Compensation could absorb a large portion of any future fee revenue.

***Politician:** "As the proverb says: "the hungry stomach will not respect the environment and tell you to go to hell". There has to be work...then they can respect the environment. We need planning, water, agriculture, tourism ...*

***Politician:** The Island's sustainability in the long term is dim. We are 99% dependent on handouts... The priority for the young is jobs...most people have no job so they go to the sea... I think (tourism) is the only salvation of Rodrigues*

***Civil servant:** Good idea, but ...(firstly) you have to have the product in place (biodiversity). You can't invite people into a warehouse where there is nothing to buy.*

***Politician:** I am not sure what brand we will finally have officially but diving will be very important in promotion. So – ecological, marine park, environmental protection.*

4.4 Study limitations

MPA/McPA boundaries were not specified in the survey but most marine recreational activities are in any case concentrated in or near parks as proposed. The possible side-effect of depressing WTP levels was seen as preferable to any overstatement of WTP at early project stages in relation to changeable park boundaries. The approach used permitted a general island-level discussion here considered suitable for ICZM.

5. DISCUSSION

To enhance their resilience, islands can benefit from management as social-ecological systems to overcome local but also external uncertainty, such as climate change enhancing coral destruction (Tompkins and Adger 2004). MPA in small islands aimed partly at management of tourism may help limit such risks, particularly when set up within effective Integrated Coastal Zone Management (ICZM) frameworks (Cicin-Sain and Belfiore 2005). Some island MPA use such approaches – at Bonaire and Saba in the Caribbean and the Marshall Islands' Jaluit Atoll in the Pacific – but this is rare in the Pacific and the Indian Ocean. The financial benefits of MPA to small islands is recognised within the context of UN development efforts for Small Island Developing States (Lutchman 2005; UN 2005). However, local acceptance of such MPA and ICZM policies from various constituencies may still depend on degrees of economic benefits or resources they secure (Christie 2005). Results suggest this will be no different in Rodrigues and issues of equity in distribution of benefits of MPA need consideration.

This chapter set out to determine whether WTP for Marine (and Coastal) Protected Areas in a remote French-speaking island of the Indian Ocean is as limited as suggested in earlier studies (Depondt and Green 2006). Tourists' WTP in Rodrigues appears promising. A general fee to use a Marine and Coastal Protected Area offers perhaps better immediate potential than a user-targeted diver fee regime alone for an MPA, as the diving sector remains undeveloped. Assuming a total tourism base of 50,000, Rodrigues could raise 350,000 euro immediately through a 7 euro weekly visitor charge for a McPA, or half that amount if only 50% paid. This could perhaps be charged more broadly to all visitors to the island, as applied successfully in the Galapagos islands. A separate, or perhaps additional, 30,000 euro could be raised for the MPA alone if just 5,000 people paid a 3 euro fee twice to snorkel or dive during their visit. With an expected expansion of tourism to 100,000, and dive participation rates of almost 50% among survey respondents, this highly conservative estimate may

be easily achievable and quickly surpassed if Rodrigues' unique but niche diving conditions are effectively marketed. A mixed fee regime could be explored for its potential to add to revenue potential (Wallpole, Goodwin et al. 2001), including perhaps blanket island visit fee as successfully applied to all visitors to the Galapagos islands (Baine, Howard et al. 2007). The revenue levels suggested above for land and sea protected areas in Rodrigues compare favourably with those reported for MPA elsewhere that are cited as successes. Apo island in the Philippines has raised \$38,000 p.a. from divers (Alcala and Russ 2006) and \$100,000 more from tourism generally. In the Caribbean, at Bonaire's similar land-sea Marine Park, 92% of departing dive tourists agreed to a proposed entry fee of \$10/diver/year (Dixon, Scura et al. 2000). A fee of \$10 has been considered for covering costs at Belize's highly-visited MPA. If developed carefully, a wide range of both marine and non-marine sports and excursions offer further scope for fee generation in Rodrigues, as in the Seychelles (Cousin Island, Seychelles: \$160,000) (Cesar, van Beukering et al. 2004).

Of particular relevance to charging MPA user fees in French-speaking islands, this study highlights nationality as a key determinant of reduced WTP potential. There was no clear reason for lower WTP among French-speaking visitors to a French-speaking destination as a broad range of factors tested in our study in Rodrigues were inconclusive. Further investigation may reveal whether this is part of a wider trend in French-speaking destinations. A person's socioeconomic status, cultural ties and experiences are reported to influence how people perceive environmental quality (Bird 1996). In small islands, heavy reliance on specific groups of visitors may amplify risks specific to that group to levels above the background level for tourism (Baine, Howard et al. 2007). For example, French visitors, used to high state provision based on high taxes at home, suggested they resent yet another 'overseas 'tax'. The economic impact of tourism in successful small islands elsewhere in the Indian Ocean region has depended heavily on close study of market preferences among visitors of different countries (Archer and Fletcher 1996).

This study also shows a link between WTP and endemic species (Cronk 1997). There is an economic incentive to protect them in Rodrigues (White, Vogt et al. 2000), given the real risk of destruction of rare plants and animals on land being repeated in the sea, where many species remain to be recorded (Heemstra, Heemstra et al. 2004). However, tourists' WTP in Rodrigues was not largely determined by their perceptions of environmental state, as also suggested in similar MPA questioning in Europe (Petrosillo, Zurlini et al. 2007). This means their WTP may be unresponsive to any future improvement or decline in habitat or biodiversity. It is however possible that some of the factors we tested for links to WTP were not sensitive enough and could have benefited from more psychographic information (Mehmetoglu 2007).

If fees are charged to tourists in Rodrigues they will need to transparently support conservation in McPAs if they are to maximise the willingness to pay for amenity (Depondt and Green 2006). Diver WTP extended to higher fee brackets than WTP for all respondents for a McPA, as shown by the plotted relationship in Figure 12. This may be difficult as there is clear pressure for MPA in Rodrigues to include a primary economic development commitment at local level, as in other African contexts (Francis and Torell 2004). Tourism amenity benefits may be unclear in the short term, even though Rodrigues recognises the need to link biodiversity to tourism (Anon. 2006). There is a long-term risk that tourism will expose shortcomings in Rodrigues' small resource base, as in other islands, while failing to deliver social-ecological resilience at island level. Case studies from the Indian Ocean, where tourism is expanding well above global rates suggest that tourism already poses such risks to Mauritius (Ghosh, Siddique et al. 2003). Studies suggest conservation can only partially slow biodiversity decline, partly because protected areas serve multiple functions (Dietz 2003). With the above in mind, Rodrigues face risks of non-compliance and a consequent lack of difference between protected and non-protected areas leading to reduced fee potential as reported for MPAs in other French-speaking islands of the Indian Ocean. Potential

WTP will also need to be balanced against actual willingness to pay, if fee regimes are set up, and quantified studies of willingness to accept such policies among fishermen, which it was not possible to include here (Arin and Kramer 2002; Onwujekwe, Hanson et al. 2005). Ultimately, MPA success and failure in reconciling conservation and tourism in sustainable development policies are highly specific to location and management styles and cannot be guaranteed (Oracion, Miller et al. 2005; Alcala and Russ 2006).

5.1 Policy implications

- User fees offer scope for funding costs of integrated approaches to sustainable development, including new Marine (and Coastal) Protected Areas in the Indian Ocean (Rodrigues).
- Reliance on tourism from a narrow visitor base may entrench low WTP potential. On the other hand, historical ties to former patron countries can be economically important to islands (Bertram 2004).
- Attracting high earners could raise overall fee generation potential, as in Seychelles, but at the risk of elitism (Charnley 2005). Rodrigues egalitarian culture and the small size of the island raises risks of resentment if overt displays of wealth and control of assets by outsiders becomes normal.
- Poor access and marketing of remote islands with limited economic options (Briguglio 1995) may create sub-optimal patterns of tourism associated with low WTP.

- McPA may need to be better marketed or branded at island level to draw tourists with high WTP to help fund integrated land and sea conservation strategies appropriate for small islands with high endemism (Roberts 2002).
- Branding research could help identify tourists with expectations and perceptions matched to island realities (Nunn 2004; Prebensen 2007). Rodrigues lacks the kind of clear and positive 'Brand Personality' discussed for Africa (Pitt, Opoku et al. 2007).
- Endemism common to remote islands (Cronk 1997) offers scope for raising WTP, as in Seychelles (Henri 2004), but subject to local communities compliance with MPA rules
- Demand for nature can help slow biodiversity decline but mixed goals attached to the main McPA in Rodrigues mean decline is unlikely to be reversed by the UNDP-backed McPA at Mourouk (Dietz 2003), which is also not tied into regional MPA networks aimed at raising overall regional ecological resilience. This raises questions over the point of the McPA. There appeared to be divergence among policy-makers over the balance of conservation and development outcomes expected from the McPA. The MPAs in the north from their inception more clearly focused on conservation, with development as a desirable but less overriding goal of protecting the natural resource base.
- Fishers' concerns suggest risks of non-compliance if they are not addressed. This raises risks of further fishery enforcement problems leading to MPA conditions associated with low fee potential reported in nearby French-speaking islands.

- Raising tourism to 100,000 visits/year by 2015 in Rodrigues may raise potential revenue from user fees at the risk of testing island carrying capacity (Brown, Turner et al. 1997), and possibly deterring existing tourists preferring little development.
- Tourists' flight distances and a move towards luxury hotels may undermine claims of 'ecotourism' in Rodrigues, as for many other destinations (Gossling, Peeters et al. 2004). Trade-off policies could help find compromises, perhaps involving more reliance on regional tourism but at the risk of losing tourist fees (Brown, Adger et al. 2001).
- Political will in terms of raising employment, equity, and land protection within McPA is likely to be highly determinant of final WTP as any failure may result in there being little difference between protected and non-protected areas, although WTP was not highly correlated with tourists' perceptions of environmental state in this study.
- Explorations of tourist fee revenue potential could be usefully extended to other African islands, including biodiversity hotspots at even greater risk than the South Mascarene islands in the Gulf of Guinea (Roberts 2002).

5.1.1 Limits to WTP

Where market prices or technological solutions fail, environmental policy may respond best to principles best identified and applied through political processes and participatory trade-offs between stakeholders Sagoff (2004). However, this argument does presume a level playing field for such discussion, which may be absent in both developed as well as developing countries. Participatory approaches to resource

management are widely advocated, but the process of decision-making may be heavily skewed under command-and-control regimes (Walker et al, 2002). Limburg et al call for ecosystem valuations to switch from choosing among resources to valuing "the avoidance of catastrophic ecosystem change". Interdisciplinary approaches are viewed by some as one way of overcoming such increasingly complex scientific and societal problems (Chiesura and de Groot 2004), particularly in light of the perception that both ecologists and economists are likely to lack the ability to ascertain which groups are likely to suffer most if ecosystem services become degraded" (NSF, 2000). Such approaches were not attempted in this study.

6. CONCLUSIONS

Findings presented here suggest significant potential exists to raise fees for the use of new Marine (and Coastal) Protected Areas recently announced in an understudied region where French-speaking small islands are otherwise reported to have little potential. (Depondt and Green 2006). Socioeconomic factors correlated the most strongly with tourists' willingness to pay. In particular, findings presented here indicate limits to WTP may result from over-reliance on a narrow tourism base as commonly found in some remote islands. This may be correct, but approaches which give more weight to subtle interplays between tourists motivations and preferences may be needed to allow effective advance planning of tourism strategies which include sustainable development goals based on MPA. The reasons for low WTP among French tourists in this study requires further investigation. Better accounting for wider cultural and belief systems (Stepp, Jones et al. 2003; Petrosillo, Zurlini et al. 2007; Prebensen 2007) held by tourists, and relating it natural capital (Limburg, O'Neill et al. 2002) could help raise prospects for sustainable development policy based on MPA. In Rodrigues, fishers' concerns and political realities will also need to be addressed or tourists' short term interests and related expressions of WTP may otherwise have nothing to do with 'sustainability' in resilience terms (Casagrandi and Rinaldi 2002).

Bringing tourists' perceptions and island marketing strategies into ecosystem-oriented resource management frameworks (Walker, Carpenter et al. 2002) more generally may help avoid the low WTP reported for various reasons in other MPA in nearby islands.

CHAPTER 6

Chapter 5 highlighted a need for fishers' concerns and political realities to be addressed, or MPA-related tourism and WTP (fee revenue) may have nothing to do with 'sustainability' in resilience terms. Qualitative findings highlighted cross-scale issues of political will and island remoteness as potentially important determinants of MPA outcomes.

This chapter returns to the point where broad-level contextual issues of resilience were left in Chapter 3. It leaves the long-term perspective to consider immediate, current development trends in parallel with cross-scale structural and social management issues. Planning for sustainable development in resilience terms means decisions may require multiple levels of decision-making. This chapter highlights risks of local resource users fading from sight in the co-management process, risking poor compliance with MPA and unsustainable policy outcomes. The need to preserve capacity for self-organisation among resource users at lower scales is discussed through reference to other useful case studies. The need to see MPA impacts in the wider context of development trends to which they are attached is highlighted.

CHAPTER 6

STRUCTURAL CONSTRAINTS TO TRANSFORMATION IN SMALL ISLANDS

Keywords – Co-management; livelihoods; water; resilience; capitals; ICZM; MPA

1. Abstract

Small island societies planning to move from degradation to sustainable development in resilience terms have a mixed record of success when using MPA. This chapter presents findings from a small Indian Ocean island planning Marine (and Coastal) Protected Areas (McPA) to reduce external economic dependence through conservation and development linked to tourism. Devolution of power from Mauritius to regional government in its distant island of Rodrigues, is part of the process, with co-management planned for the main McPA. Semi-structured interviews with 70 key informants revealed commonly-held perceptions of drivers of degradation and prospects for McPA success as part of the solution. Influential stakeholders differed in their perceptions of island development needs and style, with institutional weakness, poor linkages and capacity emerging as potentially critical barriers to change. A lack of trust in private and public life emerged as a critical obstacle to adaptation, whether for planned or unplanned social, economic and ecological change. A further 93 fisher-farmers took part in a quantitative survey, giving closed and open-answer questions about their perceptions of causes of degradation and solutions. Causes included illegal fishing, linked to population pressure and unemployment. Enforcement, jobs and then MPA were identified as solutions. MPA risk being imposed with an overriding prioritisation of development over conservation. Tourism development may conflict with conservation. Agriculture, as a linked livelihood option, carries similar risks of degradation. Both are limited by and risk adding to water constraints typical in small degraded islands. Co-management urged by donors may take time to embed in societies used to openly flouting rules. Overall, cycles of island-level degradation may be perpetuated, with local resource users left to their traditional switching mix of fishing and farming or emigration. Case studies in resource management from other parts of the world may inform Rodrigues' plans, including strengthening capitals, reviewing tenure, and identifying winners and losers and policy trade-offs while preparing for instability and climate change.

2. INTRODUCTION

For small islands short of local development options a rapid expansion of tourism potentially offers a route out of dependency to a commercially successful economic future (Bertram 2007). Such transformations often involve changing the scales and

nature of cross-scale relationships (Kinzig, Ryan et al. 2006), and the emergence of a new kind of system – or a new way of “making a living” (Walker, Gunderson et al. 2007). The drivers of local economic well-being in small islands may well be symptomatic of un-sustainability at higher scale (Kerr 2005; Armitage and Johnson 2006), with development bubbles bursting due partly to uncontrollable exogenous threats to relative local advantages. Constant Stock (CS) policy approaches (Kerr 2005) to such “sustainability” easily leave its meaning open to interpretation, while sustainability approaches emphasising decisions based on stakeholder participation may be unacceptable to governments (Brown, Adger et al. 2001; Tompkins and Adger 2002) with perhaps a “command-and-control pathology” (Holling and Meffe 1996). Selecting institutions to deal with such risks is problematic. Studies in two-island states in the Caribbean suggest that key determinants of cross-scale interactions are the exercise of relative power between stakeholders, involving issues of domination, resistance, cooperation and access to information (Adger, Brown et al. 2006). Such cross-scale power relations between user groups (Armitage, Marschke et al. 2007) and relative marginalities (Hollup 2000) raise issues of inequitable distribution of benefits in the context of coastal management. Overall, governments or communities acting alone often have not been reliable for tropical biodiversity conservation (Barrett, Brandon et al. 2001; Berkes 2004). Within Integrated Coastal Zone Management, institutional barriers to change may arise from characteristics and differences between actors, cultures, networks, relationships, ministries and goals (Cicin-Sain and Belfiore 2005). At local MPA scale winners and losers may emerge in efforts to blend conservation with tourism development (Oracion, Miller et al. 2005; Alcala and Russ 2006; Garnett, Sayer et al. 2007). This may be a particular risk in small island regions. Of 36 destinations recently categorised as Small Island Tourist Economies (SITE) eight of nine with the highest levels of tourism penetration were political dependencies (McElroy and Morris 2003). Contextual cross-scale issues of climate and water are

under increasingly critical pressure as natural resources in such islands (Pigram 2001; Pahl-Wostl, Craps et al. 2007).

2.1 Aims and objectives

This chapter considers potential constraints to reconciling top-level priorities and bottom-up aspirations (Christie 2005; Jones 2005; Christie, Fluharty et al. 2007) for conservation and development in a degraded two-island state facing rapid feedbacks across land-sea interfaces caused by human and natural stressors. Is co-management just a fig-leaf for co-option in authoritarian political cultures with little experience of such approaches? Do structural barriers to change pose critical risks to MPA in Rodrigues Island (Mauritius)? In this chapter these questions are approached by:

- Reviewing early plans for Marine and Coastal Protected Areas
- Eliciting illustrative fishers' perceptions of lagoon degradation and solutions in the context of island resource use and development trends
- Identifying cross-scale structural barriers to resource management change
- Summarising issues and proposing models for MCPA decision-making at local level

3. METHODS

Methods described in earlier chapters were used for interviewing influential stakeholders and fishers. Fishers' perceptions were otherwise elicited through survey questions included in surveys described in Chapter 4 (Shifting baselines). Perceptions and comments from influential stakeholders were elicited in a similar format to methods outlined in Chapter 3 (Resilience), with recorded semi-structured interviews transcribed in English and summarised according to key issues emerging in relation to chapter objectives. The determination of constraints, opportunities and risks inherent in

development sectors most related to island strategies linked to MPA proceeded as described in Chapter 3.

4. RESULTS

4.1 MCPA project background

4.1.1 Twin-island development

After Mauritius' became a Republic (1995) its nearby dependency of Rodrigues dissolved its Local Council Act (1992) in favour of autonomy (Rodrigues Regional Assembly Act, RRA 2001) inspired by the two-island system of Trinidad and Tobago. Greater economic independence and sustainable development for the island is desired by Mauritius and Rodrigues but has proved elusive to date. Future development in Rodrigues is likely to focus on agriculture, forestry, agribusiness, tourism, fisheries and other "emerging sectors". A Sustainable Integrated Development Plan (SIDPR) initiated in 2006 (KPMG 2006) was to be underpinned by new local provisions in Mauritius' Environmental Protection Act (EPA 2002). Millennium Development Goals (MDG) informed provisional priorities of economic and environmental sustainability, unemployment and poverty reduction and improved of life quality. The RRA presented such moves as "empowerment" (Budget speech 2006) within the Executive Council's stated goal of an "ecological island". SIDPR referred to continuing "close" two-island inter-linkages, downplaying some historical local desires for this to be otherwise: "total separation might take a considerable time". Participatory planning was preferred subject to "integrating Rodrigues' development needs prominently into national processes and planning" and the caveat that "ownership that begins with national leaders does not necessarily translate into bottom-up commitment". Despite clear environmental degradation, Mauritius (Ramessur 2003) was proposed as a development model, whose "strategy adopted ... to pull itself out of the doldrums of the

1960s was not applicable to Rodrigues" (sugar/textiles/export zone). Rodrigues' poverty levels have been the highest (37.5% in 2001/2002) in middle-income Mauritius with 30% levels of 5-year unemployed recorded despite stabilising out-migration, while social security and welfare took up 15% of the 2002/3 budget - at 1.03 billion rupees already twice the 1996/97 level. Together with wages and salaries accounting for 67% of the recurrent budget in 2004/5 Rodrigues islands' dependence on Mauritius was clear as the MCPA project set out with a four-year timeframe.

4.1.2. De-centralisation and environmental management

The granting of semi-autonomy to Rodrigues is seen by central government as a critical step in improving Rodrigues' island environment, assisted by revisions to the 2002 Environmental Protection Act Protection. Sustainable management of coastal and marine biological resources was at the time of planning provided for in the National Environment Strategy (1997), the Ten Year Plan for the Fisheries Sector and others, notably National Physical Development Plan reports (Anon. 2003). Rodrigues' Executive Council (RRA) has to develop legislation in consultation with the State Law Office for the protection and of marine resources and daily management of the island. District Councils are responsible for detailed planning and development approvals at village and community level.

4.1.3. Marine and Coastal Protected Areas (MCPA) in Rodrigues

MPA were first recommended for Mauritius shortly after independence (Robertson 1974) before the main island's massive coastal modifications for beach tourism (FAO Project for UNDP: DP MAR/72/004/2). No effective action was taken but with environmental problems now apparent MPA are receiving more attention. Two Marine Protected Areas (MPA) have been declared on the main island. Blue Bay (353 ha) and Balaclava (485 ha) were established in 1997/8 but they have suffered from high

administrative and enforcement costs. The coral reef ecosystem in Mauritius is considered to be overexploited, and damage to the reef is recognised as having serious consequences for tourism, fishing, beach stability and both marine parks and reserves (Ramessur 2002). Mauritius recently had 70% tourist participation rates in reef-based activities, contributing to environmental pressure. Conflicts had arisen between the fishing and hotel industry over coastal expansion of hotels and sand extraction, for example. In Rodrigues, severe lagoon damage due partly to human activities on land was notably reported in 1988, ahead of a major marine survey 10 years later (Burnett 2001; Oliver and Holmes 2004). Rodrigues began substantive work on its MCPA in 2005/06. The proposed Mourouk MCPA area (84 km²) in south-eastern Rodrigues (Co-financed by UNDP-GEF: MAR/03/G35/A/1G/99) includes a 4km wide section of lagoon and several of Rodrigues' 18 islands already used to a limited degree for recreation. A large channel (Grande Passe) (200m wide to 47m deep) runs for 2.5 km. Within it lies a section (Port Sud-Est) with an existing fishery reserve (approx. 0.16 sq km), of which extended boundaries were to form the basis of the new MCPA. Rodrigues' four northern MPA (marine reserves gazetted in 2007 totalling approx. 24 sq km) were proposed by a UK/UNDP-GEF (Small Grant)-funded local NGO before regional autonomy (Gell, Lynch et al. 2003; Anderson 2005; UNDP 2006) (Figure 1). One site reached implementation (Rivière Banane -1.5 sq km) in 2007, with others pending its results.

4.1.4. MPA co-management

Details on all projects during this fieldwork survey were limited to boundary outlines. Both for the fisheries reserves and the MCPA individual aims and objectives remained unclear. The MCPA was most outwardly committed to participatory co-management for sustainable development. Proposed by UNDP and the Mauritian government rather than Rodriguans, it was to serve as a model demonstration site for Mauritius itself – in

essence acting as a donor-funded policy test-bed on a separate island. The MCPA and reserves were developed and delineated without close coordination, with rivalry and political considerations reportedly hindering progress. Both projects referred to socio-economic development as desirable beyond biodiversity protection and fishery enhancement. Due to a lack of current clarity on the reserves research here focuses on the MCPA (UNDP 2006), whose early aims included:

- Setting up an enabling policy and institutional framework for the sustainable co-management of MPA throughout the Republic of Mauritius, with Rodrigues as a representative demonstration site
- Innovative, iterative and adaptive co-management
- Critical "hidden objectives": a) a fiscal model with legislated political support for sustainable co-management of MPA and marine resources within the Republic of Mauritius b) identifying sustainable alternative income sources for the population currently dependent on the lagoon for their livelihood

Details of fisher consultation and organisational structures across scales were unclear and at best provisional, but Community Resource Committees were to be represented on a Rodrigues island level Integrated Marine Protected Area Management Board (IMPAMB) reporting to the Regional Assembly. It is expected that CRC staff selected by fishers at each landing stations will send members and report to a higher Community Advisory Council reporting the IMPAMB. Final power structures and linkages, responsibilities and reporting remained to be decided but participants were likely to include tourism, fisheries, NGO, enforcement and government officials, with 4 fisher members out of 12, compared to 3 people from one marine NGO delineating the northern reserves. Initial plans for involving fishers in co-management included; participation in developing use zones and restricting access; data collection; protection of habitat and resources from damaging fishing practices; compliance through participation in development and enforcement of rules and inclusive long-term decision-

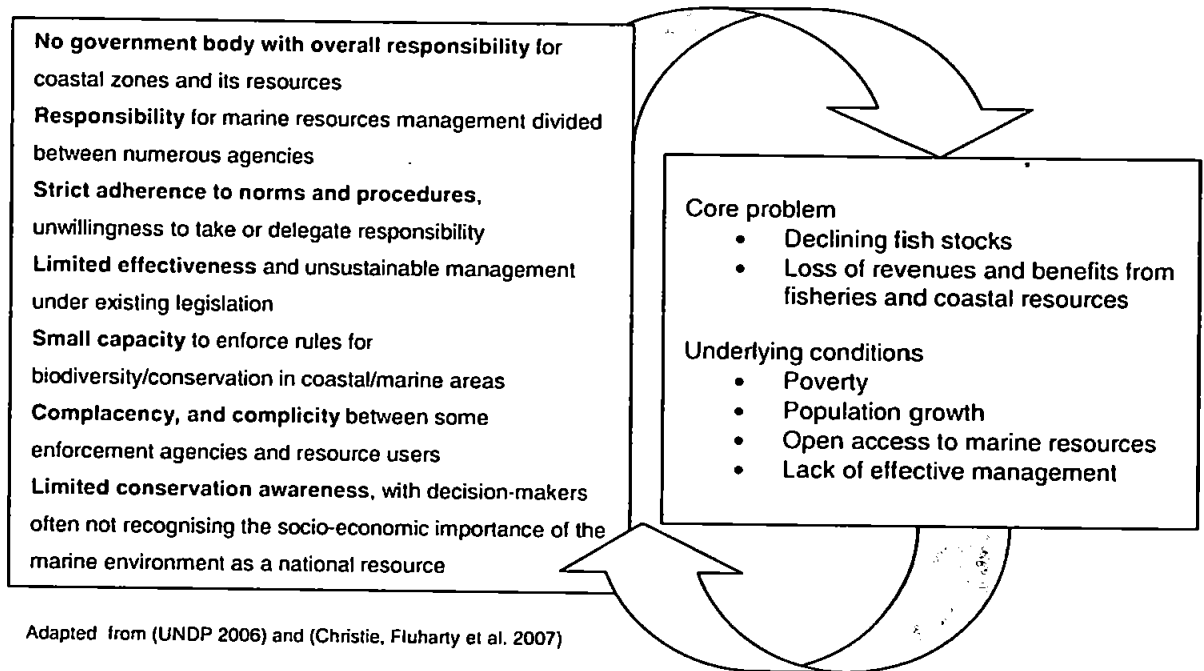
making. The MCPA was viewed as a sub-set of SIDPR by Mauritian planning officials (Fisheries, Agriculture, Tourism and Cross-sector issues).

Substantive socioeconomic and biophysical baseline assessments had not been completed before boundaries to reserves and the MCPA had been drawn, although preliminary scientific assessments indicated promising areas. MCPA boundary outlines had been mapped for reasons of which UNDP officials interviewed were unaware, and which they acknowledged did not necessarily reflect fishers' viewpoints. Mauritian officials indicated the biodiversity goals had shifted to development over time. Boundaries at one point suggested in ecologically intact and biodiversity-rich far southern lagoon areas were by-passed in favour of boundaries in a poor, populated coastal area with notable land-sea degradation but tourism development potential. Fisheries reserves in place constituted a convenient legal template for expansion. Rodriguan leaders to highest levels were concerned over political risks of reducing fisher access to grounds, as effort risked intensifying beyond boundaries into the ecologically healthier zones in the far southern lagoon. In qualitative interviews in 2005 fishers' knowledge of MCPA plans was minimal or non-existent.

4.1.5. ICZM

The MCPA project started in 1995 in the absence of an Integrated Coastal Zone Management Plan still in planning in 2007. ICZM aims included a local network of managed MPA strategically placed to benefit in turn from the interconnectivity of the marine environment under a Mauritius-wide ICZM project (ICZMP). ICZM is aimed partly to overcome perceived past constraints to effective policy, which in many respects relate to key marine fisheries problems and contributing factors highlighted for ICZM in the Philippines (Christie, Fluharty et al. 2007) (Figure 16).

Figure 16: Illustrative cycle of degradation by failure to address institutional aspects of marine resource use: problems identified in Rodrigues related to common ICZM fisheries policy issues



4.1.6. Donor and other external linkages

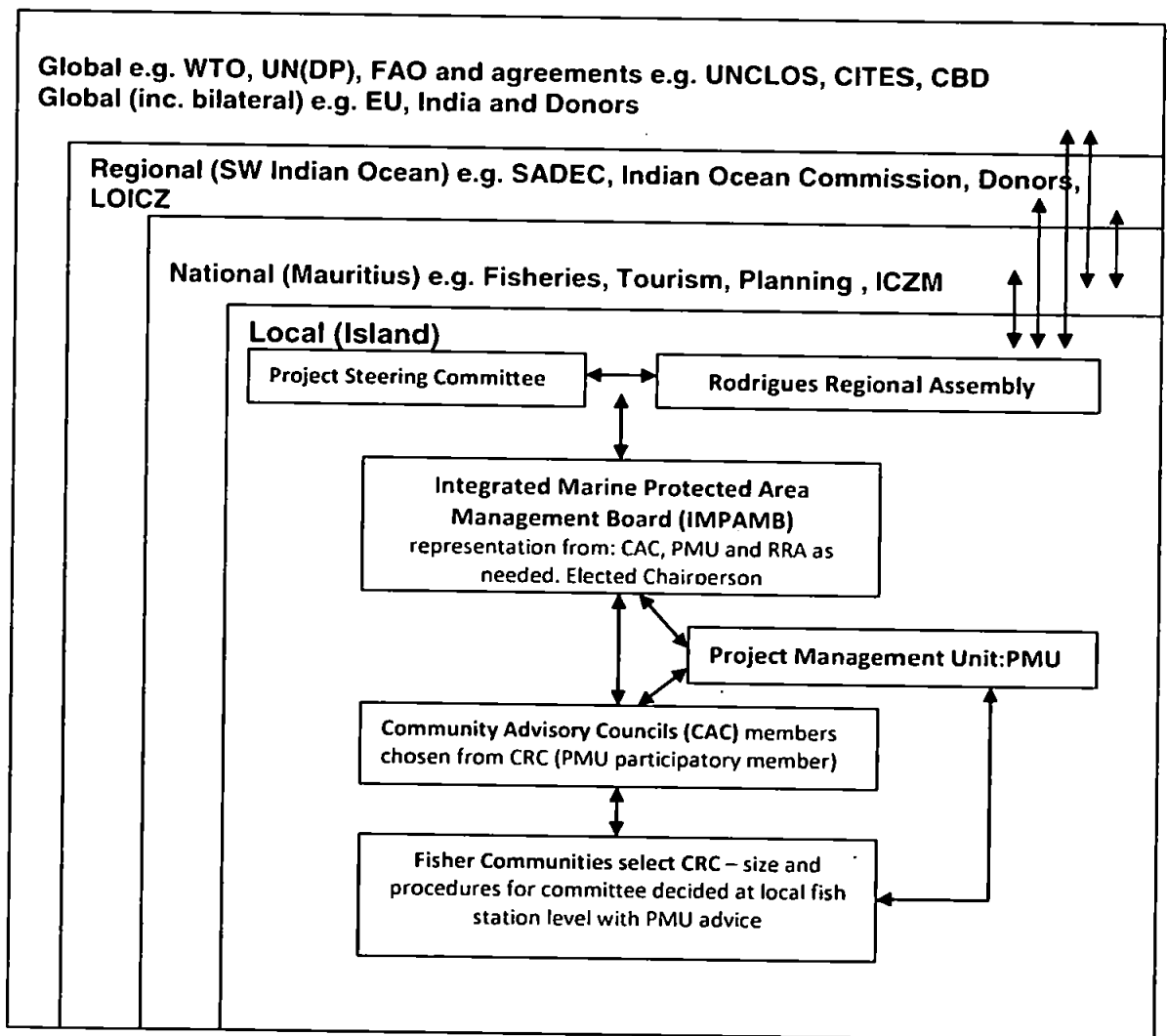
Funding issues for conservation remained critical issues for project success. Rodrigues has new powers (RRA 2001) to seek foreign donor aid if channelled through central government. UN and British donors were most clearly committed at early stages and the island has a clear interest in seeking such funding as budgets fall. Other recent donor programmes ahead of MPA implementation included International Fund for Agricultural Development (IFAD) projects aimed at encouraging cooperatives for off-lagoon fishing (initially unsuccessfully due partly to gender, finance and boat leasing issues). The end of a major anti-erosion project by the European Union was followed by a poverty alleviation programme (2006), Decentralised Cooperation Project (DCP), with strict terms involving local and national government (with the former as a "Non-State Actor"). This included fisheries, agriculture, governance and small business initiatives, without explicit links to MPA aims. Former colonial powers Britain and

France appointed diplomatic consuls on the marginal island of 38,000, which together with a papal visit before autonomy suggests growing outside recognition. The MCPA was not linked into regional MPA plans, and the first reserve outlined in the north was minimal in size and unlikely to provide bio-geographical function.

4.1.7. Summary

Co-management arrangements in Rodrigues were not finalised in 2007 but Figure 17 shows how the MCPA project is nested within wider hierarchies each with institutional priorities and overlapping spheres of perhaps direct and indirect local influence:

Figure 17: Rodrigues' Marine and Coastal Protected Area nested within national, regional and global hierarchies



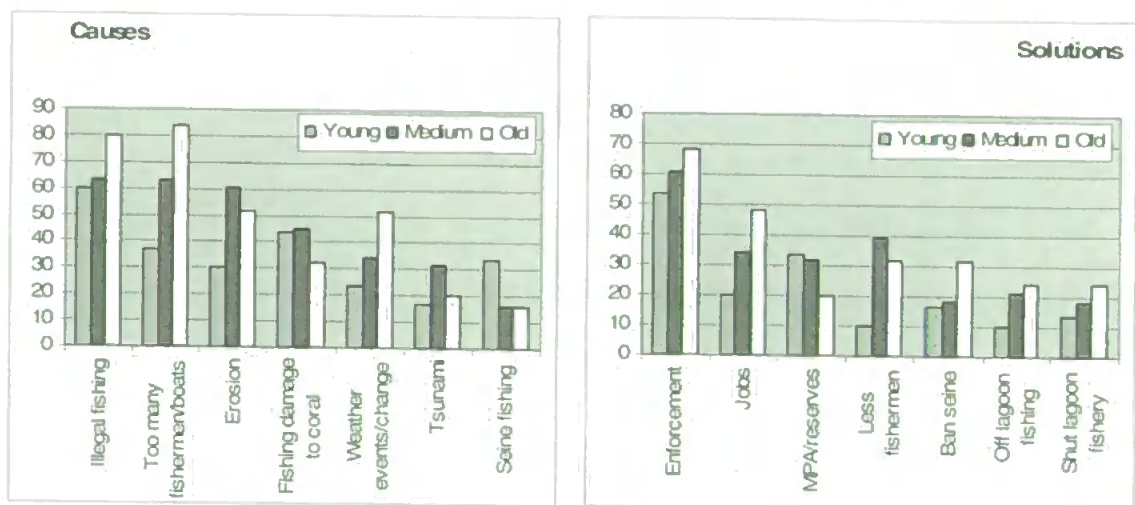
4.2 Fishers' perceptions

This section presents survey findings of fishers' perceptions of causes of lagoon decline, and perceived best solutions. These are placed within the wider context of island degradation, resource management and development trends. Institutional issues are then considered to identify obstacles to successful co-management before a discussion of findings.

Earlier chapters describe how MPA implementation in Rodrigues was preceded by inappropriate land use leading to soil erosion and land degradation, with dispersed settlement adding to degradation of landscapes and biodiversity. Coastal zone degradation extended from shoreline to reefs and fisheries, while issues such as solid waste and sewage disposal, and intensification of farming, pose risks to water catchments, aquifers and the lagoon. Destructive fishing methods, unsustainable harvesting of fish, octopus and molluscs and high sediment loads from inappropriate land use in the catchments area are recognised in earlier studies (Bunce, Rodwell et al. 2007) as past causes of habitat and coral damage in the lagoon area, with ineffective management as a contributing factor.

4.2.1. *Causes of degradation and solutions*

Such concerns relate closely to perceptions of fishers (n=93) surveyed in 2005, providing a basis for consultation. Three generations were asked to suggest up to five unprompted reasons each for causes of lagoon coral and fishery decline, and solutions. Answers, given by over 10% of respondents, and including 75% of 621 statements, also reflected fishers' appreciation of their own agency in degradation. This was less apparent with each new generation in terms of how this linked to natural

Figure 18: Main causes of fishery decline and solutions suggested by >10% of 93 fishers

stressors and land-based activities (Figure 18), raising a need for increased awareness among youngsters.

Causes: Coral and fish decline were attributed to human more than natural causes. Older fishers referred most to natural causes of lagoon decline – in particular droughts, cyclones, climate change, heat-induced coral death (35%) – or impacts such as soil erosion and lagoon depth loss (48%). All ages cited illegal fishing as most damaging (67%), followed by concern over fisher numbers (60%). Youngsters focused more on illegal fishing and human damage to coral (41%), particularly seine and octopus fishing. Perceived impacts of the 2004 Indonesian tsunami raised concern among all. Examples of feedback loops between humans and climate change cited by fishermen included land-erosion due to farming and deforestation leading to infilling of lagoon areas. This forced fishermen to drive fish more often by foot than from boat – a more physically destructive practice due to repeated footfall of 20 or more people smashing poles into coral more often to dislodge fish towards nets.

Solutions: As a solution to fish and coral decline, fishers prioritised fishery enforcement (60%) and job creation (33%) and/or social security or compensation (8%). Younger

fishers gave fewer responses but were more supportive of MPAs spontaneously proposed by only a third (29%) of all fishers. A minority proposed various kinds of fishing bans, notably seining (21%), but also octopus (6%), walking on coral (7%) or lagoon fishing generally (18%) – whether through seasonal or longer-term closures. In participant observations fishers often considered that enforcement was a priority that overrode a need for MPA, an issue which if tackled through effective application of current laws by itself would reduce the need for MPA. Another issue not tested formally in surveys but apparent in interviews related to a sense of community solidarity – which often included comments suggesting that if any fishers were to be banned from an area, the ban should apply to all – with total lagoon closure an option. Issues of access for some fishers but not others, in whatever combination, often raised fears of non-compliance already discussed as fishers' main priority discussed in greater detail in the next section. The exception was men quite prepared to see women excluded from fishing (largely octopus fishers and gleaners) as part of what often appeared to be a case of finding a scapegoat for all environmental damage to reduce the need to change personal habits. This is not presented as proven – but it was very apparent as a trend in opinion apparent during participant observations lasting over two months at sea.

4.3 Alternative income sectors

This sector develops fishers' perceptions of solutions to degradation in developmental terms dependent on cross-scale linkages to Mauritius and institutional structures likely to determine MPA management. The most likely alternative income sectors of tourism and agriculture are discussed in this chapter in terms of contextual stakeholder perceptions indicated in Appendix 9. As the risks of fishing itself as a continuing source of income are already developed (Bunce, Rodwell et al. 2007), this chapter focuses on enforcement issues raised by fishers themselves as a risk to its outward expansion.

4.3.1 Livelihood pressure

Contrary to fishing and agriculture, employment growth rates in commerce, tourism and restaurants, for example, have recently have been the highest of all sectors since 1993 (33%) but unemployment has still risen sharply, with a 172% increase in 1997-2001 alone (CSO 2005). With 6,148 new jobs needed by 2008 alone there are continuing risks of rising human pressure on the stressed fishery often considered to be an option of last resort. As Mauritius looked to cheaper migrant labour alternatives from Asia in 2006/7 the trend may continue. For youngsters, post-primary school drop-out rates (68% vs. 39% in Mauritius in 1990 to 44% vs. 32% in 2000) fell after recent mandatory attendance (1993) but expectations and development pressures are rising. Mauritius' main island's experience suggests development could bring rapid and damaging feedbacks in Rodrigues' lagoon.

4.3.2 Fisheries (Enforcement)

Interviewees' comments suggest the fishing sector is characterised by a continuing lack of alternative sources of income. Perceived problems in the fishing sector included inappropriate incentives; low awareness of impacts of fishing and poor practices; inadequate cross-sector co-ordination and land-side pressure with risks enhanced by a lack of local knowledge of their inter-actions with the sea. There is a lack of cooperation between government departments reported by interviewees, who in some cases pointed to specific inter-island problems in cooperation over enforcement. Notably Rodrigues' Fisheries Protection Service (FPS):

"... appears to be a total failure ... running in an inefficient manner and in a haphazard direction. Despite several requests, no data or information were obtained from the FPS ... No interview could be scheduled and no assessment could be conducted" (Official report)

The FPS is accused by fishers and officials alike of evasiveness and breaches of the Fisheries Management Act 1998, which it is supposed to enforce. Interviewees indicate that FPS is unable in its current form to address fisheries conservation within marine resource management. MPA managers saw enforcement and political will as key obstacles, in turn related to wider scientific risks of raising expectations over uncertain MPA outcomes:

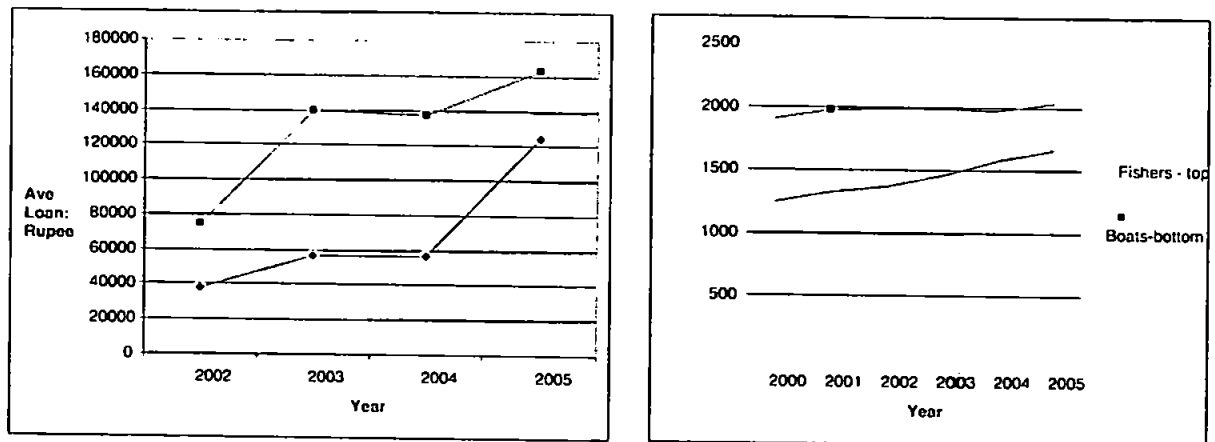
"I think enforcement...(and/or no clear MPA) benefits. People need to see benefits. In five years time if there isn't a change memory and tempers will fray. It is a leap of faith because people are believing the scientists ... (but) we are not sure exactly what is going to happen. You need to have the MPA being valued by the locals spiritually, emotionally and used by tourists to get that cash."

Fisheries data are widely believed to be unreliable, along with those supplied by the official Fisheries Research and Training Unit. Fish catch is often unrecorded by FRTU and evidence of illegal fishing visible to any close observer both day and night is pervasive but unaddressed both by the FPS or National Coastguard. This presents risks to MCPA success apart from scientific debate over the extent of biological benefits that may accrue to fishers under varying reserve zoning conditions to be finalised in coming years. Together with expansion of tourism this carries risks:

"The fishermen see the divers ... nice big fancy boats with fancy engines and when they are working they are obviously making good money ... So there is a certain amount of jealousy ... if fishermen are losing by having an area taken awaybe careful" MPA planner

Interviewees repeatedly indicated a lack of trust at all levels over fisheries enforcement, and beyond investment in capacity, material or joint approaches between FPS and fishers a number of interviewees proposed outsider (non-Mauritian) enforcers as the only answer. Participant observations revealed day and night illegal fishing with impunity. Nets and gear are caught by fisheries guards rather than people, who at most face fines and ineffectively mounted court cases. Jails in Rodrigues have never been busy. Fishers we encountered called for harsher penalties for fraud, whilst admitting that they or friends were involved.

Figure 19: Left: Fishing loans (Mauritian rupee) showing upward trend (middle) led by sharp rise in off-lagoon sector (top, n=23, with 283% rise 2002-05) vs. lagoon (bottom, n=277, 26% rise) Data courtesy of: Development Bank of Mauritius (left) Fisheries Protection Service (right) Right: Fishing boat registrations rising faster than stabilising fisher numbers.



"Can the FPS do it not? What you need is someone to come in from the outside with a good number of patrol boats. Rodrigues is a family - everyone knows each other. There are cousins, 'uncles and aunts'. You can't harm people. People would say X, here is your (seized) net, go! I would go to the shop next day and buy another." Seine fishermen (and political advisor)

Poor enforcement will likely extend offshore if the fishing sector is expanded as expected to meet rising local, national and international demand, including tourists. As an alternative economic activity to lagoon fishing some MPA managers are doubtful of benefits and fearful of feedback effects of offshore fishing:

"I think it is closely related to what is happening in the lagoon. I do not have any data again but it will not be sustained for long, if you begin to tap this resource" Donor official (MPA)

Off-lagoon fish catch as a proportion of the island's total rose from 1% to 26% (1997-2001) while octopus catch doubled from 329 to 707 tonnes. Figures obtained in interviews with the near-monopoly Development Bank of Mauritius (Figure 19) show the extent of loan take-up for investment in off-lagoon gear (large mesh traps) capable of inflicting significant damage to coral, even before finalisation of policy. Offshore fishing, for which final development formats have to be decided, is a priority of both political parties and national government.

Table 16: Tourism strategic projections for Rodrigues, with overall island water demand

	Base 2000	Year 5	Year 10	Year 15	Year 20
Tourist accommodation (rooms)	380	580	780	903	1,090
Air tourist arrivals ('000)	38	57	84	104	121
Tourism receipts (000,000 rupee)	109	161	230	281	316
Local incomes generated	110	163	232	284	319
Local employment (FT job equivalents)	963	1425	2,038	2,487	2,800
Overall island water needs (inc 30% loss rate cu metres/day)					
Low	7601	-	15045	-	17,662
Medium	8664	-	15045	-	19,138
High	9374	-	18121	-	22,827

4.3.3. Tourism

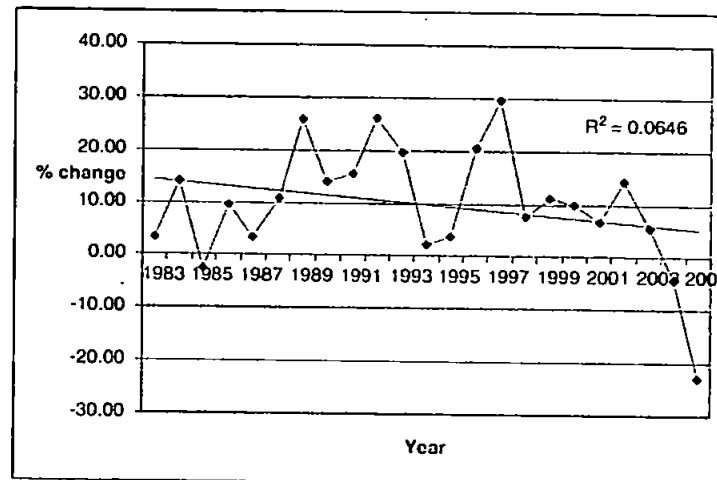
Policy-makers globally are increasingly alarmed about the effects of mass tourism on the economic, environmental and socio-cultural fabrics of receiving areas, including small islands with water shortages (Pigram 2001). Tourism expansion in Rodrigues may have a considerable impact on the island (Table 16) and its already stressed resources, including water critical to development of any alternative income sector for reducing fishing activity:

"If tourism increases there will be an increased pressure on the reef. That is automatic. Because when tourists come and they want to eat seafood and when the demand is increasing, the pressure (is) increasing..." NGO

4.3.3.1 Uncertainty

MPA are widely regarded in Rodrigues as a key strategy for promoting tourism. However, a "lack of long-term vision and comprehensive sustainable planning" has characterised Rodrigues' tourism sector. A National Physical Development Plan for Rodrigues laid out policies for "flag-ship" and medium-sized hotels, guest houses and tourism facilities but these and a succession of consultant reports were little implemented. In the absence of clear planning and effective Environmental Impact Assessments the tourism sector generally fails to present a common front and is characterised by local infighting and splinter grouping.

Figure 20: Annual % change in tourist arrivals in Rodrigues island. Less marketing of Rodrigues after autonomy, economic recession in Mauritius, a lack of local infrastructure and vision and higher oil and air travels hit tourism to Rodrigues after 2001



Data source: CSO 2005/KPMG

At national level, interviewees perceived Rodrigues' absence in the post-autonomy marketing strategies as contributory to employment uncertainty evident in fluctuating annual tourism percentage growth (Figure 20). Mauritius dropped Rodrigues from its marketing strategy and events after autonomy in 2001, leaving the island divided over strategy and with scant resources for pursuing a campaign of its own. Terrorism in 2001, rising oil prices and air taxes and ticket prices thereafter appear to have combined to cut even regional island trade from main island Mauritius and Reunion as a base-load of tourism. A Mauritian national carrier near-monopoly on regional air routes to Rodrigues, the pursuit of perhaps inappropriate beach tourism strategies saturating other longer-standing resorts in the region (Mauritius/Seychelles) and the spread by aeroplane of Dengue fever in the region in 2005/6 may have all added to Rodrigues' steep fall in tourist visits, leading together hotel and travel agency closures.

Rodrigues set up a Tourism Committee in 2006 but National Assembly reviews and budget approvals constrain the extent of independent local choice. Tourism as a priority sector lost some of its allure after autonomy, with unpredictable occupancy rates of 20-60%. Hotel closures and lay-offs in 2005/6 in Rodrigues created social

problems and prompted staff to move into other sectors or emigrate to Mauritius at the same time as MPA were connected publicly to tourism-related employment creation:

"This is the issue, and there is not enough tourists coming through" MPA planner (NGO)

The risks of downturns in tourism leading to high vacancy rates is more general (Ioannides and Holcomb 2003), creating financial burdens for luxury accommodations with high capital investment and fixed costs often above those for small establishments that may close periodically or partially as a tactical survival strategy.

4.3.3.2 Style

Tourism styles are mainly directed from Mauritius and local wishes to offer a distinct alternative are subject to those of better-capitalised Mauritian developers and promoters.

"Marketing campaigns focus on the Mauritian destination and do not differentiate between the identities of Mauritius Island and Rodrigues" ... (data on tourists, tourism projects and organisational linkages are minimal)

Upmarket hotels are often owned by "foreign" (Mauritian) companies and rely heavily on imports of items not usually manufactured locally. This involves economic leakage and perhaps greater export of un-sustainability to higher scales (even after taking into account local damage through sand and coral dredging and illegal de-rocking of hillsides). Smaller accommodation providers in Rodrigues may be more resilient in being able to open and close in response to fluctuating demand but even at local level there is disagreement over which style of tourism development is "green". Such arguments also take on a political hue, related often to personal interest and concern over perceived "Mauritian domination":

"I have felt that and it is weird because at the same time you are talking ecotourism, you are talking about nature islands (developing unused lagoon islands) and all this stuff, but at the

same time you are talking about Sea Food Hubs, bigger hotels coming up, so I feel that in the politics in the government they do not really know what they are talking about" Donor official

Small accommodation providers also often cater more for visitors from Reunion. This by-product of inter-island Creole cultural affinities with Rodrigues carries risks of tourism trade diversion away from Mauritius and is seen by some as a development choice with sensitive national political and economic overtones:

"The problem is maybe there, because from what I see and from tourists I have met they prefer Rodrigues rather than Mauritius. So, apparently you would have a by-pass of Mauritius and people coming here to stay on holidays. So that would be ... (laughs)" (Kept anonymous)

Many Rodriguans are concerned over saturation by beach tourism models used in Mauritius, with development sprawl in prime beach locations in or next to proposed MPA boundaries.

"I think there is huge serious question mark over the future capacity of Rodrigues to attract tourism, particularly if they are going in this current (hotel expansion) direction" (NGO)

4.3.3.3. Benefit capture

There appear to be risks of wider capture of MPA benefits by elites. Some local politicians appeared in interviews to favour those from which they derived greatest political support, or else reflected personal interest. This extended to issues of where roads are built. With car registrations rising sharply (376 to 660 in 2001-2004 alone) tarred coastal roads are expected to extend to border reefs in prime beauty spots underpinning tourism. Rodriguans generally do not use beaches much and such development risks being tourism-driven and styled. Land lease grants for hotels recently proliferating on the islands' most attractive natural coastline as MPA plans advanced were surrounded by bitter accusations of cronyism and land speculation at local level (a lease may be handed on upon sale of buildings on the site).

Suspicion surrounds the transparency of land agreements in Rodrigues. Ad hoc tourism promotion by Rodriguans is often driven by local elites wealthy enough to set

up on their own or secure undeveloped leases on potential hotel plots. Small local accommodation offerings are considered sub-standard and unworthy of marketing, again leaving elites – including former government officials and/or their supporters – well-placed in a niche. A hotel owner with a near-monopoly on lagoon tourism activities within current MCPA boundaries recently failed in an election bid for the coastal hinterland, although his political patron went on to island leadership. Some fishers expressed concern that tourism operators will benefit to their loss through closure of fishing areas where marine sports are still allowed. Poorly perceived Environmental Impact Assessments add scope for negative environmental impacts of tourism.

4.3.4 Agriculture

Rodrigues' agriculture slumped after the 1970s, due partly to drought but also youngsters emigrating to other jobs in Mauritius since the 1980s and a subsequent focus on backyard cash crops. Land use decline continues amid poor market prices and outlets, farm credit, low yields, water shortage, uncontrolled grazing and weather impacts. A National Development Strategy for Rodrigues (Anon. 2003) is not statutory but a possible 5-10% (or more) increase in used arable land from 3,200 hectares has been mentioned, along with larger scale farming on undeveloped fertile western land. Despite evident decline and land degradations agriculture is still considered by influential interviewees as a key option for reducing fishing effort. Fishers often farm to some extent and could raise farming activity if encouraged:

"I think we will try to look at the opportunities. We have to get fishermen into agriculture on the terrace (and) at the same time fight against land erosion. Rehabilitate terraces, plant on them, develop for example maize so that others can grow pigs if they want and process these pigs and find a market. We will try to develop the whole chain, from vegetables to the processing plant and the marketing"

Such an expansion remains limited by water but also a lack of technology to attract youngsters disinterested or deterred by pick-and-hoe farming, lease delays, insecure

tenure and other disincentives. Crop diseases are not effectively controlled or monitored and wandering animals threaten crops and add to soil erosion. An overall lack of information for land planning means lease applications are slow, affecting personal and economic decisions. Leases and plots of land have “not always been allocated in a judicious way”, with squatting and dispersed settlement adding to infrastructural impacts:

“There is a lot of land on Rodrigues which is abandoned. You just need good management. They have lots of big problems of land tenure because lots of people have already got leases, and you can’t take the land from them, and the land goes to the kids, and the kids work in the government. So the land is left abandoned. And this hampers erosion as well. Lots of land is abandoned and the government, I don’t know if they can take it. Some they can’t take, and some they don’t want to take” Forestry NGO

In interviews, political opinion on the island appeared to be split between farming along existing lines - with greater use of inputs and high-yield stocks - or else developing larger-scale commercial farms closer to dam sites. Farmers responded to past drought, and market demand in Mauritius, by prioritising acclimatised local lemons, chillies, and red beans, along with livestock and agro-processing – including honey. For various reasons results have been disappointing (pests, disease, cross-breeding, poor marketing, drought). Pork production is being expanded and other livestock may follow if fodder, pasture and other wider production cycle failures are addressed. A possible return to traditional culture of cassava, sweet potato, banana and maize (used in traditional cuisine attractive to tourists) adds to erosion risks from livestock along with a resumption of wood fuel cutting. New cattle-grazing rules could limit this. Pesticide use and lagoon impacts are also largely not monitored and impacts could rise due to tourism and a shift of fishers back into farming. The main produce farming areas in turn face continuing water stress, signs of saltwater intrusion and soil salination.

4.3.5. Water criticality

Tourism and agriculture are considered as key sectors for alternative incomes for fishers. For both, Rodrigues' water storage is perceived as a critical limiting factor to development. Many farmers rely on rain-fed water, meaning they are hit hard in droughts, even with roof-top collection tanks common on the island. Donor projects to built infrastructure were soon subject to sedimentation from erosion, although successfully boosting table produce on a site since subject to possible salt-water intrusion. A large dam to overcome silting problems limiting the usefulness of small-scale projects completed so far may not be resolved for 20 years, but estimated water demand for irrigation alone (under scenarios of no restriction on water supply - 4,000 cu m/day - and no additional supply 1,650 cu m/day) underline uncertainty over the island's future landscape. Perceptions of nepotism and corruption add to such uncertainty, with the most fertile eastern end of the island with flat land least supplied:

"It (water distribution) is not generally on a political basis but I do not think it is done in an efficient way ... (pause) ... maybe for the water tankers, water lorries, and all this. I have been told they do it on a political basis. But this is not good, water is a necessity. Land lease also .. they have been preventing people from having it. Mainly people who are have the same political opinion as them" Leader of the Regional Island Assembly

Decisions on water are widely seen as critical to the island's general viability. The construction of such water intensive facilities to diversify the tourism sector may mean water shortages have to be met by energy-intensive desalination, in turn requiring expensive fossil-fuel imports and the construction of new power generation plants. Peak power demand in Rodrigues is rising sharply – from 3.8-5.6 MW in 2000-2004 alone – with a three-fold increase in diesel feedstock oil, for which prices continue to rise. Per capita water and energy demands of tourists in upmarket luxury facilities generally exceed those of mass tourists, domestic visitors and local residents (Ioannides and Holcomb 2003). Although western consumer tastes (inc. bathroom

water usage) are more common the island has no piped sewerage, which together with a proliferation of land-standing pit latrines, and hotel septic reception facilities on land poses risks of groundwater and lagoon pollution added to unmonitored pesticides and fertiliser levels. Such patterns develop although the impacts of climate change-related water stress on global populations is already likely to be considerable (Arnell 2004), and groundwater availability in a island with overstretched reserves may be further reduced as a result (Ranjan, Kazama et al. 2006). Considerable capital inputs from higher scales appear to be needed.

4.4 Institutions and culture

Having explored some of the complex development issues most closely associated with MPAs and plans to reduce fishing, this section summarises some of the key cross-scale institutional and social issues that may affected policy determination through planned co-management. After a review of influential policy-makers' perceptions relating to institutional effectiveness we summarise them with reference to similar experience in other twin island states before discussing overall findings.

4.4.1. Power

A general lack of clarity over institutional linkages and responsibility in Rodrigues extends to delimitation of powers between the two islands:

"There is a certain amount of dichotomy between what the new Rodrigues Administration thinks they do or can do, and what the Mauritians think they can do. And in a sense both of them don't know ...It is a bit of paralysis...both expecting the others to do the work." MPA planner

This may be resolved but government officials suggest autonomous powers will take time to establish at the same time as MPA implementation accelerates up to 2008:

"(Power split) ... It's basically clear. But after three years of autonomy, it's not certain it's clear to everyone. In practice, much more difficult and arduous ... It is a success, but I would say it is a struggle which will continue. We have to conquer, acquire and fulfil this autonomy. It's not good enough to have it on paper, you have to have it in law but it has to be real. And on that point the battle is not won." Former Minister for Rodrigues

4.4.2. Coordination

Interviewees perceived a pervasive lack of coordination between government departments both at inter-island level and generally, which could affect optimality of fisheries decisions. Due to the importance of such perceptions to MPA and ICZM a typical viewpoint follows (Box 4):

Box 4: Perception of institutional weakness in MPA context

"From my point of view, there is not much cooperation between departments. There is not much collaboration... it's not designed for clear working methods. My lack of clarity I think is indicative of the general lack of clarity ... There's the Ministry of Fisheries, and even I am not sure how it works. The Ministry of Fisheries retains responsibility for directing research and policy development on Rodrigues as there is not the capacity yet within Rodrigues for them to do it ... (and there are) issues between (Mauritius Oceanography Institute under Prime Minister's office) and the Mauritian Ministry of Fisheries which is well known to be a poorly run, poorly funded ministry which achieves very little. Even among Mauritians it does not have a lot of respect. It is funded mainly by Japanese money and its progress is small...slow process ... lack of capacity ...initiative." MPA planner

The nature of coordination of MPA with other projects at planning stages was unclear, and the future uncertain. One key project manager was doubtful that development priorities would take sufficient account of conservation needs in terms of preserving ecological goods and services. His comments underlined wider perceptions of a lack of cooperation on cross-sector development issues of economic and/or local strategic importance:

"Developing all these – off-shore fisheries, hotels – I don't see anyone thinking about conservation. In the end it is not about how you link projects to get them to work. What we need is for people to work together rather than: "you do this side and the others do their side ... The government's priority is a development goal...and to make sure that the fishermen are happy because they have great power...a great part of the population is fishing. It is a big electoral pool" (MPA official)

4.4.3. Island-level approach

Many of the cross-scale issues relating to forestry management in terms of arguments for and against community-based management (Tacconi 2007) apply to coral reefs. Participatory projects already managed in Rodrigues' forestry contexts, with participants themselves selecting plants for commercial culture (excluding exotics) appear to hold lessons for marine reserves. However, NGO cooperation itself is at times uncertain due to rivalry and a past unwillingness to treat land and marine issues as one. Were it to be so, issues of trust between resource users still pose more fundamental issues as described in Box 5. NGOs are instrumental in significantly advancing island conservation agendas – a role referred to by some in government as “agents of change”, but some officials also regard them as outsider-driven organisations meriting suspicion. Rodrigues in turn remains subject to post-independence suspicions of desiring to by-pass Mauritius and deal with third countries.

Box 5: Perceptions constraints to co-management of natural resource in Rodrigues

Land-based resource management

NGO: We learnt a lot of lessons (forestry). To start with it was very successful. Nurseries were run buy the community, and we got the plants produced and planted. But then it came to management of plants.

MPB: What were the main lessons you drew from the experience?

NGO: The first thing is you cannot have a project with plants for only two years. Funding was not for enough time ... We learnt that it is difficult to bring people together to manage one plot on a fully voluntary basis. It starts well and then people lost interest. We thought people would be – and were, very motivated - but not as we thought until the end of the project. We wanted the people to take over this project but we had to continue managing it after the (donor) funds ran out.

MPB: So did people start going back into the parks to take what they needed?

NGO: That is the problem! ... (You can take that for the marine reserves)

Marine Resource Management

MPB: Is there any scope for local communities getting together and forming committees which would be able to run maybe one per region of the island. So people in the west ran (that reserve) and people at this end did the (other)?

NGO: Not really. I think it would be run by the local authorities.

MPB: Why are local communities not strong enough to run them? What do they lack?

NGO: Faith – not faith but we will not be able to trust them. Well we could, but they don't trust themselves. We happen to have this talk in some villages, where we say: 'OK we could get some fishermen to stop fishing and work as rangers'. Some would say: 'Huh, this one (man) would take everything at night'. So they don't trust themselves. It's difficult.

Box 6: Development vs. Conservation priorities in key sustainable policy application

Mauritian managing EU project: Rodrigues is an integral part of Mauritius so when you are talking about the poverty initiative, good governance and small and medium enterprises Rodrigues is a participating party. But when you talk about the fourth element, it is uniquely for Rodrigues. That is resources management.

Researcher (author): But isn't that the most important?

Official: No, it is not the most important. Perhaps poverty is the most important. Everything that is in SIDPR has been put in motion by UNDP (funding both MPA projects to differing percentages with small and medium-sized GEF facilities). They have an integrated sustainable development programme – which is the aim. We are going in the same direction.

4.4.4. Priorities

A more practical strategic risk was that donors handling different projects on the island appeared to moving in different directions reflecting divergence between Rodrigues' new responsibilities for the environment and evident Mauritius development priorities on the other (Box 6).

4.4.5. Capacity and funding

Rodrigues is financially unsustainable absent significant cross-scale funding from central government in Mauritius. Interviewees wanted autonomy to work in Rodrigues' favour, but the island is poorly placed to insist on directions, particularly as Mauritians indicated rising resentment over Rodrigues' per capital island budget demands:

"I think it is a bit of a burden because it has highlighted something. The Rodrigues Regional Assembly is an entity of its own now. Previously, Rodrigues and Mauritius had one budget and people did not see the demarcation. Now, many people look on them as a separate entity. I can tell you (that for) a lot of government institutions ... the big feeling is why should Rodrigues, with 35,000 people, cost us budget-wise 1.3 billion? (rupee)" Mauritian official

As Rodrigues assumes more powers – and costly responsibilities for island environmental management to rectify degradation - development is accelerating with little idea of the island's human carrying capacity. This carries risks in terms of pacing and sequencing of development, and also measuring MPA results in terms of official development goals:

"We do not have (an island carrying capacity assessment). Under our project for poverty we feel there is no solid baseline for poverty assessment" (Donor)

Autonomy also brings risks of turnover of staff due to more elections, on top of pre-existing resentment over a predominance of Mauritians in key roles for which local capacity is lacking. Rodriguans often perceive Mauritians as accepting postings as a profitable overseas posting simply to be endured for personal gain, without real concern for the island:

"This new (Rodriguan) guy did not know anything about the project...so we do not know if someone new will come to the Marine Parks division ... If you have to do this every two years it could be bad" NGO

Interviewees frequently commented on infrastructural gaps – including water shortages - in terms of Rodrigues' ability to meet its long-term needs (water availability, capacity, finance, business growth). These were acknowledged by the island's Regional Chief Commissioner (see interview excerpts in Appendix 10) shortly before his appointment in 2006 after an impromptu election held after growing social unrest over his predecessors' locally perceived inability in austerity budget negotiations with central government officials to preserve longstanding social security for fishers.

4.4.6. Socio-cultural constraints

Rodrigues' socio-cultural differences to Mauritius were an ever-present background to interviews concerning development and political relations between the two islands. Such issues are less discussed in policy documents to the extent expressed in interviews but there are exceptions, underlining official recognition of what remains a divisive issue in an island that has managed since independence to balance multi-ethnic demands. Rodrigues is viewed as a net exporter of labour to mainland Mauritius, with poverty seen as a main driver.

Box 7: Development, culture, and inter-island population trends (equity and migration)

"Changes are required not only in terms of social behaviour but at other levels as well. The entire society from its highest decision-making to the farmer or fishermen has to become more productive or efficiency oriented. We do not want to create a mini-Mauritius or any other country but retain the authenticity of Rodrigues. But we cannot plan for a society where inequality exists. For example, many of the poor families in Rodrigues are female-headed households which typically have a larger than average family size" (KPMG 2006) with male emigration underlying a falling male-female sex ratio, and contributing to the Rodriguan population in (e.g. Black River) Mauritius

Interviews with central government officials suggest the government favours a significant change in culture on the island (Box 7), often expressed in terms of development not forcefully related to conservation. Rodrigues' weakness cited by Mauritian officials included a lack of enterprise and work ethic, or "culture of working together", and out-migration and low skill retention.

Perceived strengths included ethnic homogeneity, participatory spirit, political stability, established institutional structures, dynamic NGOs, good tourism sites and autonomy giving Rodrigues' leaders an "incentive to inject economic dynamism". This it is hoped will in future overcome what many elites accepted as a valid stereotype of Creole fishermen - drunken layabouts.. Such views of fishers at times add to a polarised atmosphere of distrust (Hollup 2000) voiced in Rodrigues to some extent along party political lines reflecting support-bases among fishers and/or inland farmers – although dividing lines are blurring as farming collapse means more people fish to survive. Negative views of fishers extended to donor officials:

"Well, it is pleb(ian) power! It is the people, and they ... in fact most of the population ... if they are growing (crops) they still fish. They consider themselves fishers. It is a powerful sector ... "
UNDP MPA official

Some Mauritians perceive this as simple rent-seeking and free-riding. Fishers in Rodrigues are distinct from counterparts in Mauritius but are referred to in similar terms

Table 17: Institutional constraints to natural resource management at island level in Rodrigues, within Republic of Mauritius (Adapted from Tompkins and Adger 2002)

Constitutional order	Existing legislation confusing or inadequate or non-existent External policy influence predominating (inc government, donors, supranational)
Organisational structure	Unclear roles and poor coordination of government departments / ministries Level of and effectiveness of law enforcement on land and at sea Unclear property/lease rights
Operational arrangements	Inadequate staff training in integrated/co-management Lack of successful examples of integrated management Credibility and powers of implementing agency uncertain Local versus central government Over-use of external consultants
Structural	Information shortages / hoarding (and inadequate public access) Representation of fishers poor Level of communication poor Project driven approaches with little coordination and follow-up Population slow to adapt to methods used by external groups and communities

as in Mauritius – an issue potentially relevant to respect and collaboration in any future co-management:

"You have seen it – the men drinking – it is the women holding it together. I can tell you one thing – if you leave it in the hands of the man you are doomed. I think it is difficult, whatever the situation is, but we can still say it could have been a lot worse ... You know SADEC (Southern African Development Community) are here claiming we should have 30% women in parliament and all that ..." Mauritian donor funds administrator.

Mauritians also perceive a layered society beyond Rodrigues' promoted care-free and homogenous front, with implications for wider issues of equity in development if perpetuated:

"I think also you have in Rodrigues this structure – it is layered. Some people say, you know, you have the white Rodriguans and the black ones. (Chief Commissioner X) is of a particular breed. (Former Minister for Rodrigues X) is of a different breed. You have been there – to Mt Lubin (Clair's power-base) ... so there is perhaps some kind of layering. Serge Clair was a student for the priesthood ... there is some element of that. Groups try to keep the others(down)" Government official

4.5 Summary – key institutional constraints

Significant structural risks to MPA development from an institutional perspective are raised in this section (Table 17) which relate closely to those observed in similar twin

island contexts elsewhere with apparent conflicts in setting conservation and development priorities. This section summarises key issues suggesting Rodrigues faces risks found in islands whose inter-island governance arrangements were closely observed as a model for Rodriguan island autonomy, Trinidad and Tobago (Brown, Adger et al. 2001; Tompkins and Adger 2002).

5. DISCUSSION

5.1 Key points

Findings here support growing recognition that providing an institutional framework for improved linkages between dynamic ecological and social systems is arguably one of the biggest challenges facing sustainability (Hughes, Bellwood et al. 2005). Power and marginality among groups in participatory coastal management may be critical factors determining ability to learn and enhance social-ecological resilience (Armitage, Marschke et al. 2007). Structural, organizational and socio-cultural constraints to user-participation in lagoon fisheries management exist in Mauritius (Hollup 2000) are these highlighted here as risks in the different context of Rodrigues, with or without co-management. Different ethnic and political affiliations and stereotypes may influence the interaction and cooperation among principal stakeholders and limit fishers' voice in management, while preserving those of political, economic and technical elites. It is possible that issues of equity will predominate in early MPA co-management beyond issues of economic growth, as suggested by studies showing that trust and motivation are key prerequisites of economic growth that may take time to establish after apparent absence (Marini 2004).

Overall, new institutional arrangements on an island with longstanding commons resource management issues (Gade 1985) could help forestall, limit or even avoid further repeats of open resource issues in the future (Dietz 2003; Dietz, Ostrom et al. 2003). Co-management is one such option. To make it work Rodrigues-Mauritius has an interest in overcoming deep structural and social-cultural constraints and in so doing restore ecosystems, reduce fishing pressure for rebuilding stocks and build institutions that align economic market places and self-interest with environmental stewardship and conservation. So why does this seem uncertain, and what can be done?

Mauritian and Rodriguan institutions are in a state of flux and it would be imprudent to draw too firm conclusions on prospects for MPA and ICZM management. However, cultural, infrastructural, information and institutional constraints to confused conservation and development goals could easily translate into further selling off natural capital to maintain short-term incomes by mining resources to the point of depletion. The cross-scale nature of institutional interplay (Janssen, Bodin et al. 2006) is under-researched but relevant to Rodrigues, with its new powers but limited funds. In Rodrigues, as in many countries, the structural conditions for adaptive and integrated adaptive management have not yet been determined. Findings here suggest the importance of understanding how winners and losers may emerge from institutional interactions on the basis of exercise of power through domination, resistance and cooperation (Adger, Brown et al. 2006). Likewise, at local scale, there will be issues to consider of how winners and losers may emerge from co-management of MPAs related to blending conservation with tourism development (Oracion, Miller et al. 2005; Alcala and Russ 2006; Garnett, Sayer et al. 2007).

5.1.1. Information gaps

Rodrigues' marine natural resources would appear to be still poorly-documented (Chapman and Turner 2004), biodiversity management is weak (Anon. 2005) and environmental management unsustainable (Anon. 2003). Developing marine policy and managing natural resources requires multi-scale ecological and social information. Such information needs to be deployed by managers in effective networks to address the combined and rising impacts of environmental degradation, climate change and widespread over-fishing. How managers get information, and more specifically how they may interact to use it through institutions (Janssen, Bodin et al. 2006) will be critical issues requiring more study in Rodrigues.

5.1.2. Level of decisions

Rodrigues typifies problems of managing coastal social-ecological systems to cope with change crossing up and down scales due to globalisation (Armitage and Johnson 2006). Findings here raise the risk of various levels of governments involved in coastal management in two-island systems being conflicting in their aims and in their attitudes to co-management and sharing of responsibility (Adger, Brown et al. 2006). The appropriate locus for island-level conservation in Rodrigues is therefore unclear. At a lower level, community-based methods work best when there are strong formal or informal local systems of local control to enforce access restrictions, while government run schemes fare well in the hands of a competent bureaucracy (Barrett, Brandon et al. 2001). Both may be lacking in Rodrigues. The locus of management returns to questions of resilience for what, of what, and for whom? – issues that are perhaps best addressed as trade-offs and need to include resilience also in terms of - where?, and by when? Rodrigues does not appear to have a clear direction over the balance between conservation and development. This in turn may limit the conservation focus

needed to underpin critical natural resources needed to support basic development. The reasons for this appear to be related to differing visions of the future held by Rodriguans and Mauritians upon who they remain dependent for budgets and also investment. As the islands become interconnected both social and ecological resilience may need to be considered at higher scales than separate islands – variously to national scale and beyond as a function of social, economic and ecological variables.

5.1.3. Small island institutions

The aim of treating Rodrigues as a social-ecological system unit nested within higher scales, using local knowledge (Johannes 1998), adaptive management (Folke, Hahn et al. 2005), and practices responsive to ecological feedback would appear to be desirable. However, findings here support the notion that Small Island Developing States responsible for managing a large proportion of the world's tropical fisheries may not be able to do this with institutions closely modelled closely on those of developed countries (Mahon and McConney 2004) or outside patrons. Many simply do not have the funds even where there is a will. The creation of flexible polycentric institutions and social networks in multi-level governance systems are to be desired, perhaps even as depicted here. There are even attempts underway to do this, but it is a considerable challenge. The collapse of fisheries in developed countries with sufficient funds and institutional strength illustrates this only too well.

Small islands vulnerable to natural hazards risk therefore have an interest in reviewing and rehabilitating institutions and power relationships to suit local circumstances without remaining narrowly concerned with local issues and therefore susceptible to external drivers, such as climate change, fishery recruitment failure and market demands operating at larger scales (Hughes, Bellwood et al. 2005). Institutions' cross-

scale workings are little researched but it has been proposed that successful conservation depends on:

- 1) the authority, willingness and ability to restrict use
- 2) ability to offer incentives to use resources in a sustainable way - or not at all
- 3) technical capacity to monitor social-ecological conditions, and
- 4) managerial flexibility to alter incentives and access as conditions change.

These need to be considered as Rodrigues' new institutional relationships are formed. As Barrett and Brandon (2001) point out, tropical biodiversity management is often weak, while the politics of natural resource use emphasize exploitation and redistribution, sometimes including the co-opting of purportedly community-based efforts (Gibson 1999). Few central governments – tropical or otherwise - have a real incentive to conserve resources. Findings here suggest there is political value in granting key supporters access to natural resources and land for their use and exploitation, but sometimes only a thin constituency for conservation.

5.1.4. ICZM

ICZM offers scope for addressing island and inter-island marine and coastal management issues – if managed effectively. However, actors in MPA and ICM policy circles may differ across the two-island divide, reflecting different cultures, networks of relationships, ministries and goals and motivations (Cicin-Sain and Belfiore 2005). On such small islands a doubling up of policy over a small area adds to management complexity and cost. Are both ICZM policies *and* Marine and Coastal Protected Area policies needed? Guidelines for such policy are complex, and beyond anything practiced nationally already in many small islands. It is here suggested as a matter for consideration that given the difficulties experienced in ICZM in mainland Africa

(McClanahan, Mwaguni et al. 2005) one flexible level of management might be sufficient for linking all MPA and planning issues found in smaller islands.

5.1.5. Co-management and property rights

Rodrigues' new environmental policies at early MPA planning stages risk being strongly top-down with a veneer of participation that may deliver insufficient legitimacy. Beyond the short-term, social-ecological resilience suggests a need to engage strongly with fishers, overcoming stereotypes to build trust, exchange and a sense of mutual interest instead of coercion. Inclusive institutional networks for coastal management could help in this respect (Tompkins and Adger 2002). However, arguments over community versus centralised resource management appear to have been skewed by the positive experiences of Pacific rather than Indian Ocean islands (Johannes 1998). This makes them no less valid or useful, but Rodrigues' culture is unlikely to be turned around quickly and working within current parameters to some extent may be the only practical option as degradation accelerates.

5.1.6. Strengthening capitals

Conservation and development policies around the world adopt many names but share similar philosophies (Garnett, Sayer et al. 2007) emphasising a need to build up natural, human, social, built and financial capitals. However, taking into account biophysical contexts, landscape diversity, demographic trends, land tenure, local democracy and effective sequencing of policy all require significant inputs unlikely to be handled at only lower institutional scale. Lessons from outcomes of integrated conservation and development projects elsewhere highlight the importance of:

- Recognising biophysical constraints to development; maintaining landscape diversity
- Understanding demographic trends; human capacity development;

- High governance scores;
- Stable, equitable and transparent systems of land or sea ownership;
- Sequencing of policy across scales of governance;
- Trading of natural for built capital; and finally,
- Using financial incentives in the absence of belief systems constraining environmental degradation.

Built capital is often highlighted as an indicator of development and trade-offs between natural and built capital may be needed while avoiding anarchic development patterns already seen in some areas (Fedderke, Perkins et al. 2006). Beyond the short-term, social-ecological resilience suggests a need to engage strongly with fishers, overcoming stereotypes to build trust, exchange and a sense of mutual interest instead of coercion. Inclusive institutional networks for coastal management could help in this respect (Tompkins and Adger 2002).

5.2 Case study lessons

5.2.1. Instability and “hot groups”

Collaborative, adaptive management aimed at managing uncertainty can itself be hard when institutions are weak and political landscapes are shifting (Wollenburg, Iwan et al. 2007), for example with decentralisation after authoritarian rule. NGOs and others at the front of policy implementation could well learn from “muddling through” approaches that appear to have worked in chaotic institutional contexts. “Hot groups” of spontaneously organising groups may be suited to Rodriguans’ self-proclaimed individualistic patterns of behaviour over financial matters, although sustaining such efforts and maintaining any kind of structure may be challenging. Lessons from forestry conservation in general hold useful lessons for land and sea contexts.

5.2.2. Livelihoods and enforcement

Studies of stresses and shocks to livelihoods among fishers in Cambodian coastal villages underline a need for diversification of livelihoods and institutions as a coping strategy, (Marschke and Berkes 2006). Livelihoods in Rodrigues relate mainly to fishing, farming, tourism -- and water resources -- but all have been in decline in recent years. Understanding people's perceptions of what constitutes their own resilience may be an important step towards building collaboration between communities and institutions, which in turn can help illustrate cross-scale issues unknown to communities. Given Mauritius' Millennium Development Goals for Rodrigues there is an interest in using human well-being as one benchmark of MPA success - the few studies that have considered this (Gjertsen 2005) linked well-being to MPA enforcement.

5.2.3. Reconciling "win-win" priorities

Any confusion over whether to pursue fishery management, tourism or wilderness management could threaten long-term resource sustainability. Pro-poor tourism may be very different from pro-conservation tourism (Ashley, Boyd et al. 2000), for example, but long-standing MPAs in the Philippines suggest Marine Protected Areas can yield benefits in both ways through collective institutional management approaches (Alcala and Russ 2006). In this case, a local government unit took a lead, with NGO and tourism sectors involved as necessary. Such success is far from certain (Oracion, Miller et al. 2005), and findings in Rodrigues suggest risks of economic benefits from ecotourism accruing to elites, outside investors and institutions rather than local level resource users such as fishers. Enforcement without a sense of equity may create division demonstrating a need for leadership in reconciling bottom-up and top-down priorities. Case study lessons in fisheries and tourism management from Galapagos

illustrate ways towards developing bottom-up participation in co-management that may help limit this (Baine, Howard et al. 2007). For tourism, business and institutional planning for tourism could include budgeting to change tourist preferences, or take existing preferences into account (Garnett, Sayer et al. 2007). Tourism is often discussed for economic development of MPAs but it may also be that marginal islands need simply need to look at other options. As the ratio of humans to landscape increases a shift to knowledge based activities can be helpful (Agrawal 2001; Agrawal and Chhatre 2006). Poor educational institutions and attendance present challenges to sustainable development, just as they do for co-management.

5.2.4 Fishers, farmers and tenure

Chilean fishers' attitudes towards new natural resource co-management policy and property rights (Gelcich 2005) hold potentially significant lessons for Rodrigues on land and sea (90% state land) in terms of how resources could be better managed (Dietz, Ostrom et al. 2003). Fishers and farmers in Rodrigues are often the same people, both deriving both livelihoods from the environment. Some determinants of the environmental behaviour of farmers, elsewhere and in Rodrigues, are likely to be similar to those of fishers. To some extent they may be interchangeable and this requires more study in the context of trade-offs between farming and fishing inherent in Marine Protected Area establishment. Before even considering whether environmental degradation is passed up scales with rising tourism, an institutional failure to understand such trade-offs could mean degradation is visited on adjacent land and/or sea areas – in and/or beyond protected area boundaries. The same applies for expanding fishing beyond the lagoon. Better water resource management could be critical to any scenario. Social learning rather than technical expertise alone may help reach equitable and sustainable use patterns (Pahl-Wostl, Craps et al. 2007) and limit degradation.

5.2.5. Trade-offs

Finally, this chapter highlights Rodrigues' use of Trinidad and Tobago as a benchmark for autonomy in a twin island state with similar inter-island differences (Brown, Adger et al. 2001). Rodrigues could also learn from environmental policy decision processes used in a similar context to its own to decide the balance of tourism and conservation development. Against risks of marginalisation of stakeholders leading to non-compliance with Caribbean MPA stakeholders Tobago's Buccoo Reef Marine Park, West Indies were helped towards development compromise decisions on social-economic-ecological issues (relevant to island level) using Multi-Criteria Analysis. Scenario preferences were weighted and ranked. Government agencies with political accountability helped stakeholders voice their concerns and make decisions, rather than the other way round, without necessarily re-ordering or setting up new institutions. However, there is a risk that cross-scale linkages evolve and are maintained by organisations and institutions involved in resource management to further their own interests (Adger, Brown et al. 2006). Power relations between them do not come without perceived gain - winners and losers may emerge simply from how institutions are set up. Fishers in Rodrigues appear so far to have been served by poorly representative organisations and would appear to have little decision-making influence over the shape of the new "co-management" framework. Trade-offs, as a process rather than an outcome, may not however address issues of resilience.

5.2.6. Climate change and development

It has long been recognised that few developing countries possess financial and human resources sufficiently to address adequately the predicted impacts of global climate change (Pernetta 1992), which threatens to inflict on future generations irreversible and non-substitutable loss of natural capital (Neumayer 2007). Impacts of

climate change may not be addressed unless they are prioritised, and even then resilience may depend on a need for self-efficacy, strong local and international support networks, a willingness to act collectively and to learn from mistakes (Tompkins 2005). Adaptive management strategies can help build resilience to climate change. For example, tourism in island states is vulnerable as climate change may result in detrimental changes related to extreme events, sea-level rise, transport and communications interruptions. Mitigation and adaptation need to be considered together (Arenstam-Gibbons and Nicholls 2006) by cross-scale institutions.

5.3 Further studies

The importance of understanding environmental behaviour by fishers and farmers (Gelcich 2005), and those who are both, is a critical area for study in Rodrigues. It is perhaps best approached at the point where this more contextual thesis ends, that is when awareness of MPA is permeating through island society. Such studies, combined with trade-off Multi-Criteria Analysis (Brown, Adger et al. 2001) could potentially ease MPA planning and possible success under a co-management regime. Recent suggestions for improving the effectiveness of conservation and development policy from a capitals perspective could be usefully investigated as part of the process of identifying characteristics of environment and community needed for success (Garnett, Sayer et al. 2007). Institutional approaches to conservation and development using MPA need to be more studied generally, not just in Rodrigues as its MPA plans advance from very early stages described here.

6. CONCLUSIONS

This chapter considered potential constraints to reconciling top-level priorities and bottom-up aspirations (Christie 2005; Jones 2005; Christie, Fluharty et al. 2007) for conservation and development in a degraded two-island state facing rapid feedbacks across land-sea interfaces caused by human and natural stressors. It raised the question of whether co-management risks being a fig-leaf for co-option and whether structural barriers to change pose critical risks to MPA in Rodrigues Island. Overall it would appear to be too early to say whether such risks will be played out in Rodrigues. However, findings here support the notion that participatory approaches to resource management in the process of decision-making risk being heavily skewed under command-and-control regimes (Walker, Carpenter et al. 2002).

Fostering bridging organisations and interplay between formal and informal institutions may be critical to co-management where bonding capital is limited by cultural or geographical divide. Cross-scale use of appropriate expertise is desirable and polycentric institutions in a hierarchy of cross-scale management would also seem to appropriate for addressing island-to-global scale issues. However, there is the additional risk that lower social organisational levels brought into management may become critical slower-moving variables determining and perhaps limiting pace of change in social-ecological systems (Gunderson and Holling 2002; Redman and Kinzig 2003). Such arrangements may also remove scope for self-organisation at lower levels if too cumbersome. Blockages risk perpetuating undesired configurations and need to be identified and resolved. Creating a local ability to “muddle through” and spontaneously develop policy ideas at both regional (Lebel, Anderies et al. 2006) and lower levels may be useful insurance. Trade-off decision-making used (Brown, Adger et al. 2001; Adger, Brown et al. 2006) in a twin-island MPA contexts similar to Rodrigues could serve as a model for mobilising institutions and improving interactions

between resource users. This may help Rodrigues to overcome the “distempering, pessimistic vision of the human prospect” (Ostrom, Burger et al. 1999) inherent in “Tragedy of the Commons” (Hardin 1998) narratives so far applied to the island (Gade 1985). As MPA are established and fishing expands outward into open oceans (Berkes 2006; Wilson 2006) Rodrigues and Mauritius may limit such risks by nurturing elements of transformability through incentives, building awareness of conservation, experimenting in management, strengthening capitals and fostering adaptive governance generally.

CHAPTER 7

Core chapters are conceptually summarised in this chapter to link findings to practical policy through the development of indicators. The summary recognises that measures of the conservation benefits of MPA need to be accompanied by measures of socioeconomic success, while taking into account a wide variety of drivers, pressures, impacts and responses. A modified DPSIR model is proposed for islands as part of the summary before indicators are proposed at the end.

CHAPTER 7

SUMMARY: A DPSIR APPROACHES TO SETTING INDICATORS FOR CONSERVATION AND DEVELOPMENT IN SMALL ISLANDS

Keywords – Tourism, fisheries, MPA, ICZM, vulnerability, resilience, climate

1. Abstract

Small islands face increasing degradation due to cross-scale inter-linkages between human and natural pressure over land-sea interfaces. This paper summarises the case of Rodrigues Island, Mauritius, as it plans conservation and development policy using Marine (and Coastal) Protected Areas. The Driver-Pressure-State-Impacts-Response (DPSIR) conceptual model for classifying data is modified for reef island contexts to help policy-makers cope with planning for complexity. It reflects the little control that small islands have over external natural variables, such as climate change. However, as presented here DPSIR can also reflect how many small islands have limited or no control over external social variables. Through a synthesis of this thesis and reference to other case studies a system of island-level indicators is then proposed for Rodrigues that may be relevant to tropical islands as they plan for MPA. Indicators can encourage linear views of resource management but DPSIR can be used with them to illustrate how policy can have unexpected impacts which feed back the system as existing or new drivers of degradation. DPSIR does not so easily address how these links may occur at different scales, and at different times, raising the risks of arbitrariness when setting limits to study boundaries. Overall, DPSIR analysis may be a useful policy tool for reducing island degradation, and moving island social-ecological systems move toward what Holling's conceptual Adaptive Cycle model (1973) describes as a phase of recovery. For MPA, this often involves reconciling conservation and development goals – a task usefully approached from a broad island perspective as a first step away from focusing too much on local MPA boundaries.

2. INTRODUCTION

Human responses to change (Gunderson and Holling 2002) are key determinants of societal success or failure (Diamond 2005; Abel, Cumming et al. 2006). Coastal ecosystems with rising populations are particularly subject to feedback effects between social and ecological pressures increasingly linked to intense environmental change

(Turner 2000; Adger, Hughes et al. 2005). Small islands are often the most exposed to such risks and impacts (Pelling and Uitto 2001; Cherian 2007), with tight feedback loops between environmental stressors and drivers on land and sea (Kerr 2005). Threats to reefs and ecosystems generally include distortion of food webs from their apex by humans, for example through over-fishing, and addition of nutrients from the base, leaving climate change, new diseases and "other human-caused impacts" to do the rest (Hughes, Bellwood et al. 2006). Coral reefs at the core of many social and ecological systems are globally threatened and face collapse (Holling 2000; Scheffer, Carpenter et al. 2003). Most reefs are located in tropical islands, many of which have poor conservation records due partly to a lack of capacity and information (Barrett, Brandon et al. 2001; Payet 2004). To protect renewable and non-renewable ecological goods and services (Moberg and Folke 1999) managers of such reef-dominated ecosystems could benefit from understandings of ecosystem function and change that recognise the role of humans as a constituent part. They may choose from a widening array of policy instruments but few provide managers with holistic, coarse-resolution approaches (Mangi, Roberts et al. 2007). Indicators provide a way of linking social, economic and ecological aspects of social-ecological change, including measurement of outcomes of policy potentially contributing to adaptive governance for coping with uncertainty (Folke, Hahn et al. 2005).

3. CONCEPTUAL FRAMEWORK

3.1 DPSIR

A search for new ways of considering factors that lead humans to have adverse effects on the biophysical environment, with less reliance on aggregated values, began in the 1960s and 1970s. The DPSIR (Driving forces-Pressures-State-Impact-Response) framework, which embraces processes and indicators of environmental function,

evolved from origins in social science (Vandermeulen 1998) into a management tool for understanding such linkages, variability and change. DPSIR is useful as it consists of a closed loop and displays different interactions between drivers and components. This helps determinations of feedbacks, synergies and trade-offs between different decisions and other responses, taking into account drivers at specific scales and over varying spatial, temporal and organisational dimensions (Alcamo 2003). DPSIR follows causal chains from a root cause to a direct pressure and finally a management response between interacting components of social, economic and environmental systems. To this extent, DPSIR is able to assist with ecosystem-based approaches to marine resource management, adding a degree of flexibility to interpretations without the need for over-reliance on quantitative or monetary-based research approaches, which nevertheless do form part of this study. DPSIR has been used for identifying and categorising broad contextual issues, inter-linkages, feedback mechanisms, knock-on effects of activities and responses (Elliott 2002). Applications include ecosystem, governance, sectoral and technological issues at local, national and global levels, whether for managing a specific project or just serving as a conceptual framework (Elliott 2002; Doody 2003; AidEnvironment 2004).

“... a multi-sectoral approach is essential to fully evaluate changes in ecosystem services and their impacts on people. The multi-sectoral approach examines the supply and condition of each ecosystem service as well as the interactions among them” (Alcamo 2003).

Using DPSIR, Turner (2001) proposed an interdisciplinary approach to water catchment and coastal zone management which included a consideration of many elements recognised as being of direct relevance to coastal zone MPA (Christie 2005; Christie, Lowry et al. 2005; McClanahan, Mwangi et al. 2005; Christie, Fluharty et al. 2007). DPSIR has since been applied in varied coastal and water catchment

management contexts (Casazza, Silvestri et al. 2002; Bowen and Riley 2003; Olsen 2003; Trombino 2003; Belfiore, Cicin-Sain et al. 2004; Rogers and Greenaway 2005).

DPSIR was used to analyse socioeconomic issues, environmental changes and policy responses of coastal fisheries in Kenya to select indicators for evaluating over-fishing and destructive fishing practices (Mangi, Roberts et al. 2007). Of particular relevance to this case study, DPSIR has been considered for application in Mauritius' Integrated Coastal Zone Management plans (Ramessur 2002).

3.1.1. DPSIR and integrated island MPA

In terms of social-ecological resilience, and achieving desired configurations, indicators are needed to determine when there is a risk or reality of thresholds being crossed between one state and a regime shift to another (Walker 2004; Walker, Gunderson et al. 2007). Indicators may enhance ability to learn and adapt in this way without over-reliance on mechanistic approaches to resource management, such as Maximum Sustainable Yield (MSY) of a fishery, which have demonstrably failed to account for complexity (von Betalanfly 1950; Pimm, M. et al. 2001; Roberts 2007). Coastal management depends on indicators of change cross land-sea interfaces in social, biological and ecological terms (Ehler 2003; Christie, Lowry et al. 2005). Integrated Coastal Zone Indicators may at the same time help determine the success of MPA in human development terms (Ashley, Boyd et al. 2000; Gjertsen 2005) that build active support among communities, while perhaps also highlighting cross-scale vulnerability and the need for adaptive capacity to cope with climate change (Brooks, Adger et al. 2005; Krishna 2007). MPA have proven potential for delivering rapid fisheries and wider ecological benefits across boundaries (Roberts, Hawkins et al. 2005; Roberts, Reynolds et al. 2006), but in local practice these are often reduced or obviated by policy failure to take account of contextual and often determinant social and economic

factors(Christie 2004). Feed-backs of MPA-related tourism can quickly exceed social and environmental carrying capacities of small islands, whittling down amenity and revenue upon which it depends (Arrow, Bolin et al. 1995; Brown, Turner et al. 1997). By facilitating trade-offs (Brown, Adger et al. 2001) indicators may help refine conservation and development policy (Garnett, Sayer et al. 2007) on islands and determine whether conservation does indeed lead to long-term reduction of biodiversity decline (Dietz 2003; Dietz, Ostrom et al. 2003) when development is a parallel goal. As local scale policies are scaled up indicators may be linked and compared in the context of wider impacts of globalisation across scales (Gibson, Ostrom et al. 2000; Read 2004; Wade 2004; Armitage and Johnson 2006; Butler and Oluoch-Kosura 2006).

3.2 DPSIR categorisation

Adaptive cycles used in resilience thinking allow the creation of conceptual links between social and environmental change and human policy responses. However, the adaptive cycle appears to have limited explanatory value at fine scale. DPSIR is explored here for its immediate value in facilitating change in "reorganisation" phase of the adaptive cycle that may help societies to break vicious circles of degradation. The stages are similar to those in other studies, including continental Africa (Mangi, Roberts et al. 2007), but with modifications. "Drivers" considered here in the Indian Ocean for Rodrigues island describe large-scale socio-economic conditions and sectoral trends related to the need for fisheries, tourism and agriculture at island level to both feed *and* provide surplus incomes to meet development expectations. Environmental "Pressures" build up through socioeconomic forces and may be exacerbated across land-sea interfaces by natural systems variability. "State" indicators describe island-level change in the environment and in ecological goods and services underpinning

societal development. "Impact" indicators are considered in terms of change in social benefit, while "Response" indicators are viewed in terms of policy (legislation) by institutions primarily in response to changes in State and Impact.

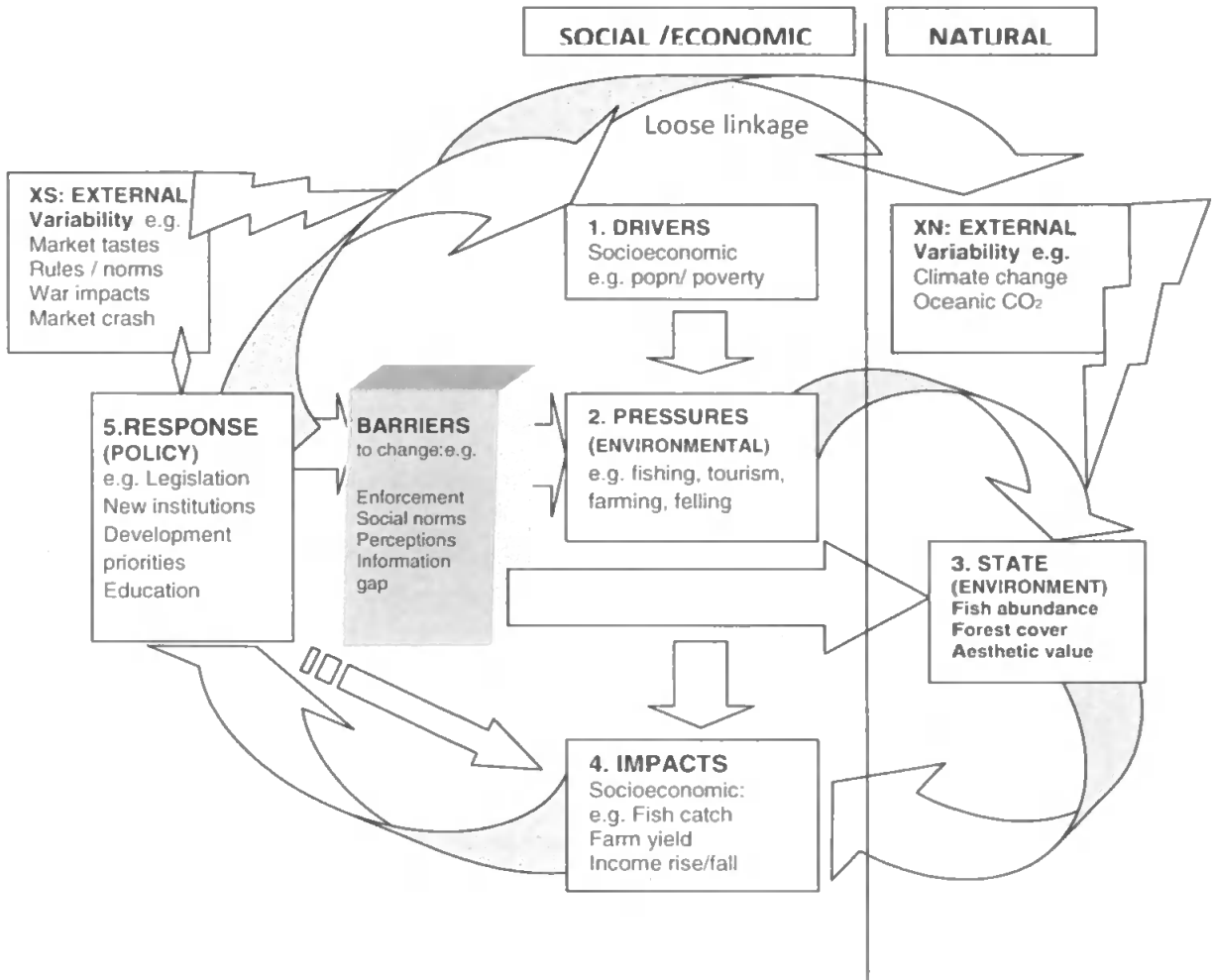
3.2.1. Proposed modification to DPSIR framework

DPSIR is not a methodology but a conceptual model that needs to reflect different realities. Those in mainland Africa and may differ from oceanic islands.

In summarising the results of this study, DPSIR is here modified to reflect the particular vulnerabilities of marginal regional islands targeting conservation and development. This may be applied with a view to assisting Marine Protected Area policy-makers determine trade-offs between fishing, farming and tourism as principle livelihoods shaping the island's social-ecological system. The value of socioeconomic indicators in MPA contexts is rarely considered but has been attempted Gjertsen (2005). The role of external determinants of variability in natural science terms are recognised in previous applications – and are denoted as XN in the modified DPSIR model above in Figure 21.

Modifications for island contexts here include recognition of island impotence with respect to affecting social and economic variables emerging or decided at higher scale. These are denoted as external variables (XS). Unlike previous applications, a loose linkage is also here created from policy response at island level to external variability. This reflects the stewardship of small islands over large areas of ocean and reefs with globally important ecosystem function. When aggregated, decisions taken by islands may feed into climate change just as for human activities generally. To exclude islands here would appear to be arbitrary. Likewise, islands highly dependent on tourism encourage highly unsustainable patterns of development, such as long-haul flights and irreversible modification of island ecosystems (Gossling, Peeters et al. 2004). These also feed into wider global patterns of unsustainable practices linked into turn to global

Figure 21: Modified DPSIR framework adapted to small islands dependent on natural resources - fisheries, farming and tourism. The 1-5 step cycle is adapted to include external variability in social/economic terms (XS), in addition to XN (natural science). Islands have only marginal /no control in both cases. However, a loose linkage is also created here between XS, policy responses and XN, reflecting island roles in sustaining unsustainable practices (e.g. marketing unsustainable tourism, open access ocean fishing) with cumulative impacts in large areas of global EEZ. Policy-makers may seek to influence XS. An extra linkage from R>I, not normally included in DPSIR models is added to represent a direct policy/non-policy option for benefit redistribution from policy “winners” to “losers” across scales.



change. In tourism, global degradation involves choices made by visitors and hosts. A third modification to DPSIR is also made in terms of the potential for redistribution through policy of benefits from winners to losers, who may be at different scales (a.g. through migration, or just taxation policy), of which the result may or may not result in feedbacks in terms of the level of pressure on resources (see arrow R>I in Figure 21).

In summarising and presenting possible indicators it should be remembered at this point that DPSIR is more a classification framework than a working quantitative model. Each box tends to be at different scale, temporal as well as spatial, and the arrows hide a complexity of pathways – not all which are known. Another caveat is that it is considered here that variables may fall into more than one category, dependent on prevalence and intensity and the scale under discussion. Following a review of chapter development and a few key issues that may be critical, indicators are suggested before final thesis conclusions are approached in the next chapter.

4. RESULTS

4.1 Case study summary: Sustainable development challenge in Rodrigues

Previous chapters have developed themes of historical determinants of social and ecological change in Rodrigues island, and an apparent failure in social and institutional terms to develop from crises towards more sustainable use of ecological goods and services. The importance of natural hazards and the nature of policy responses in shaping social-ecological configurations is highlighted in Chapter 3. Mauritius and Rodrigues aim to develop new policies for conservation and development based partly on MPA proposed by external donors. An absence of scientific baseline data to do this illustrates a need for better island-level information generally, including indicators of change upon which management may determine long-term policy affecting people's livelihoods. Chapter 4 presented a demonstration of how local knowledge and perceptions may reveal a long-term decline in marine resources, wider degradation on land and change in climate. Livelihood options to reverse the trend were explored throughout all chapters as a form of island level response diversity to change, a characteristic desirable in social and ecological terms for sustainability.

Tourism, fisheries and agriculture predominate as likely development routes related to MPA projects in Rodrigues. Tourism in particular was explored as a potential source of island income and alternative livelihoods for fishers. Diving was given more attention due to evidence in the literature of benefits in terms of MPA funding and alternative income creation. Tourism would appear to have revenue-generating potential linked to MPA to cover their costs and provide fishers with alternative livelihood. However, risks of further island-level degradation may accompany current plans for conservation and development in Rodrigues – on land, and sea - with water as a critical linking weakness. Overall, findings suggested that limiting any discussion of “win-win” conservation and development scenarios for MPAs to just local scale and contexts may be misleading. Cross-scale issues appear to be particularly relevant, if not more so. Some constraints to island-level environmental management raised in Chapter 3 appeared to be rooted deeply in island history, with implications for selecting co-management or other institutional arrangements able to address cross-scale issues. Constraints were also raised in Chapter 6. Key issues may now be summarised through DPSIR as a linking conceptual framework for identifying indicators that may promote desired policy outcomes and help in managing them to fruition and beyond.

4.2 Key research findings related to DPSIR

4.2.1. Drivers

Climate (variability and change) emerged as a critical driver of social-ecological resilience in Rodrigues – in terms of cyclones but in particular drought exacerbating fragile water budgets, and livelihood choice. Drought appears to have acted as a catalyst for social-ecological change, but many other social and natural variables also suggested throughout this thesis, with trust emerging as a common issue. With respect to DPSIR (Figure 20) cross-scale global stressors are expected to rise in frequency

and intensity (XN), while remaining largely beyond island-level control (Young, Berkhout et al. 2006). Rodrigues' additional lack of ability as a small *and* marginal island to shape the terms of its social and economic exchange with the outside world are also not unusual in small islands, and this may continue to contribute to poverty as a driver of environmental degradation. In social terms (XS), islands may still at least try to influence higher scale drivers of change, not least through island and international institutions, or through marketing strategies aimed at shifting global population perceptions. More locally, Rodrigues' relations with its neighbouring seat of central government will remain critical in terms not only of usual state function but access through it as a gate-keeper to higher scales. Rodrigues could perhaps benefit from better access to other islands with which such affinity already exists. There are perhaps steps that could be taken to build up from low levels of social capital which appear to have shaped the nature of inter-island relations and exchange for long enough to be considered as a driver. Of more critical local significance, population rise in the absence of effective measures to mitigate human impacts on the environment may re-emerge as a critical driver of island degradation. Migration is likely to remain a critical and spontaneous human response option for coping with change.

4.2.2. Pressures

Pressures in Rodrigues are perhaps best understood when allowing historical perspectives to illustrate how little in current human resource use patterns is new, beyond the intensity and cumulating impacts stemming from a rising population failing at each opportunity to change course. Whilst climate drivers cannot be addressed, poor management can, through creating conditions for the emergence of sustainable livelihood options. These may not turn out to be in farming, tourism and other economic spheres currently targeted to reduce fishing effort. Top down policy responses could benefit from fostering capacity for self-organisation in perhaps unexpected directions,

but if supplying markets at higher scale (national) is a goal then this may be undesirable. The importance of resolving pressure on water shortages is highlighted here as an immediate critical issue for any consideration of sustainable development on such a small and populated island already unable to pump required daily volumes. A key issue is how such patterns of resource degradation have persisted without creating societal collapse – and, again, this study highlights the critical safety valve of migration at times when this has been a distinct possibility.

4.2.3. State Change

Periods of dramatic social-ecological change are proposed in chapter 1 which may be repeated in future, whether related to natural hazards or other drivers. A paucity of social and natural scientific knowledge makes any determination of past state change and perhaps loss of social-ecological resilience problematic beyond the short and medium term. Shifting baselines apparent in fishers' and perhaps also policy-makers' perceptions of island states indicate the potential for perpetuating past mistakes, while forgetting there was ever anything wrong. Demonstrating what may be striking results of MPA or any other policy implementation may be difficult, while users whose appreciation of them is most needed may lose interest. Cross-scale interventions, and solicitation of knowledge and expertise wherever it exists could help Rodrigues determine social-ecological state and policy. The use of DPSIR indicators may help detect change in state. Rodrigues has an interest in developing better ecological knowledge and a parallel conservation ethic to help it become less dependent on funding from higher scales, policy conditionality, fads in donor aid, and poor uptake and long-term durability of policy and programmes already adopted.

4.2.4. Impacts

Rodrigues remains largely unstudied and attribution of all impacts to drivers is problematic. However, there appears to be little doubt that people cut down the trees and farmed with practices that, with or without uncontrolled grazing and other open access resource issues, created erosion of soil to the lagoon, where uncontrolled fishing and evidence of coral bleaching are increasingly apparent for similar commons issues. These alone are reasons for conservation action of some kind, but recent policy choices raise the risk that existing impacts will be further entrenched or new ones created. Conservation and development are presented to varying degrees as a package, but in Rodrigues there appears to be a continuing risk that conservation will fall off the agenda as development is prioritised by Mauritius to reduce island dependence. The 1970s collapse of farming was notably spurred on by climate events but also development policy choices that accelerated decline and degradation. The state of the fishery suffered impacts from development policy choices, leading to recent calls for conservation. MPA are now used for conservation but the island has yet to consider whether it can, or should, encourage a revival of farming, outward expansion of fishing and larger scale tourism. In the absence of an idea of island carrying capacity, indicators may help reveal the potentially precarious balance between conservation and development as inter-related policy plans unfold.

4.2.5. Response

The policy options of marginal islands may be limited, but as yet untaken decisions on Rodrigues' agricultural decline, water deficits, reforestation, and fishing will largely determine the context for discussing the sustainability of MPA set in the midst of an expanding national tourism. Without clear plans it is rather immaterial if tourism produces a few jobs and new sources for income if sustainability is given little thought

at any scale and past practices are perpetuated. MPA specifically are experiments, but the largest MPA in Rodrigues started with development as a main objective on a site of seemingly doubtful ecological value compared to others. Its results in terms of benefits cannot be predicted, although experience suggests there will be some ecological benefit.

Rodrigues' responses to its problems in the past seem only to have exacerbated or entrenched them, but the island is clearly not alone responsible due its dependence firstly as a colony then a small and distant marginal region. While external forces in small islands may strongly dictate the set of drivers, pressures, states and impacts in the short and long run, islanders and their institutions may yet exert influence over the actual trajectory (Bertram 2006). The question is which "islanders" - Rodriguans or Mauritians and resilience of what, to what, for who, by whom – but also by where, and by when? A renegotiation of governance relationships – in both directions – has started and if continued may bring benefits down to local management scale. A lack of trust stands out as an obstacle to building social-ecological resilience. Rodrigues suffers from low levels of trust, participation and integration at local compared to national levels, reducing the effectiveness of otherwise layered and representative institutions. Inter-island issues of trust based partly on ethnicity, and island marginality may relate to social, economic and ecological fragility through the nature of human relations and decisions prevailing at the level of institutions. The island's long-term viability in social-ecological terms may depend on such a readjustment as a two-way process for arriving at a new social-ecological configuration.

4.2.6. Migration

A key issue emerging from this study is migration. Such flows, and networks (people, goods, information, money) across scales appear to remain critical components of

social and ecological resilience in Rodrigues (Bertram 2006; Janssen, Bodin et al. 2006). They constitute a critical buffer in Rodrigues' current social-ecological configuration, while inward migration remains marginal, limiting inflows of new human capital – with visions, expertise, ideas and fresh directions. Without migration – of which patterns are not entirely clear – it appears likely that either degradation of resources would either be more pronounced, or else may have led to local responses earlier on due to falling returns. This might have occurred in a Malthusian scenario – or stopped before. The experience of Easter Island is a much-cited example whenever it comes to discussing such island stories, and its lessons are spoken of even today in Rodrigues. Perhaps it has value as a warning, if only in metaphor. Migration also may be a mixed blessing, postponing the need for local action while passing unsustainable lifestyles and economic activities up to higher scales – where they may or may not be abandoned. The extent to which migrants simply add to unsustainable practices in wider Mauritius warrants further study, and may reveal reasons for Mauritius' increasing realisation that "something must be done" in Rodrigues as the dependent island's large budget allocation creates resentment and bitter debate.

Redistributive policies are political and ideological issues for Rodrigues and Mauritius to debate, but leaving redistribution of island level development and MPA benefits to markets alone may result in short-term enforcement issues just at a time when strength and a sense of equity and legitimacy is needed for such policies with long time scales to work. Compensation – in a direct form to fishers may be needed for MPA policy to establish itself without dividing the local island population into new classes of winners and losers based partly on willingness to break laws. Livelihoods may be created at higher scales to favour conservation at lower scale, although island solidarity in Rodrigues suggests there will be much pressure for local employment. Migration (Locke, Adger et al. 2000) has opened up new livelihoods in Mauritius, helping

Rodriguans to cope with its 1970s drought crisis. It may remain a valid option for accessing compensation from higher scales. Many, not necessarily losers of past policy (although they may perceive it that way), have emigrated to Mauritius and beyond. Spectacular business successes in Mauritius and Australia or elsewhere go beyond current possibilities on the island. Migrants may also benefit less strikingly in terms of redistributive policies in terms of social housing in Mauritius not available in Rodrigues. They may also fall into drugs and crime, as seen in some enclaves. Such migration patterns and socioeconomic consequences are not studied in Rodrigues, including remittances and hidden economies. They may reveal interesting insights into the real impacts of tourism, fisheries, agriculture or any other kind of development linked to MPAs in terms of the long-term sustainability of policy in twin-island states.

4.3 Proposed policy indicators

Proposed policy indicators are directed at analytical levels that may be required for a consideration of Rodrigues in conservation and development terms. In practice, the list would be need shortening through discussion with key stakeholders (Table 18 below).

4.4. Study limitations

This summary chapter does not apply DPSIR to its full potential. Even when DPSIR is used in depth it has limitations. The level of complexity can be apparent in diagrams of linkages described as “horrendograms” (Elliott 2002), while: “The DPSIR model is a simplified portrayal ... but an analysis must navigate carefully between mechanistic reductionism and oversimplification”. (EU 2003)

Table 18: Suggested indicators for conservation and development policy Rodrigues*

Type	Indicator	Units of measurement
Drivers	Population	Island rise of fall (inc natural increase/migration)
	Unemployment / poverty	% of resident population, % under poverty line
	Education	% secondary school certificate pass
	Low social capital – bonding, bridging	Local and inter-island perceptions surveys
	Region/Global market trends	e.g. % tourist preferences / perceptions in polls
	Trade rules / externalities	\$ Macroeconomic indicators, GDP/sector
	External market demand / failure	\$ Produce/livestock differentials
	Climate variability	Standard meteorological station data
Pressures	Number of fishers	No. per sq km, boat/fisher registrations
	Excessive fishery exploitation	Catch kg/yr, Catch per Unit Effort
	Destructive fishing	Gear registration/usage patterns by time/area
	Poor farming patterns	Cultivation /sq km by type/method, inputs sales
	Livestock overgrazing, erosion	Tropical animal units/hectare
	Deforestation (natural and human)	Reported incidence, area reductions
	Squatting	% illegal occupation/ total arrears
	Consumer culture	Consumer debt to income ratio, available landfill
	Tourism development	Annual national/regional/foreign visitors and ratio
	Fish abundance	Biomass kg/ha
State	Live coral cover, Biotope mapping	% cover, Complexity score
	Sea urchin population	Density (per sq m)
	Coral bleaching/death	Change in % cover/loss
	Forest cover	% ha by species (inc reserves)
	Soil state	% change in good agricultural land
	Livestock head and mix	% change in Tropical Animal Units, % roaming
	Land tenure	Cadastral survey, government decisions
	Freshwater aquifer recharge	Daily availability (cu metres) vs demand
	Coastal infrastructure / development	% in shoreline (in/near setback limits), road kms
	Tourism	Beds / land area covered – water/power/food demand
	Tourist amenity (inc. land/seascapes)	Tourist survey, contingent valuation
	Available water decline (cu m/day)	Groundwater recharge per capita
	Lagoon water quality	Standard test monitoring
	Declining fish catch	Catch per Unit Effort (CPUE kg/fisher)
	Livelihood uncertainty	% change in income source (tourism/farm/fishing/ state or social security/state, remittances)
Impacts	Declining food security	Food price inflation, abandoned land ratio % food requirement imported, pest/invasive counts
	Falling tourism revenue	Falling revenue/ visitor night/area under accommodation (by small/large providers)
	Crowding out	% local to Mauritian/foreign help land/property
	Reduced regional domestic product	Dependence – state budget requirement
	Conflict potential	Complaints, illegal activity
	Inter-island dependence	Voting patterns, budget allocation
	Legislation	Regional Assembly /central government decisions
	Biodiversity (inc functional)	% land-sea area protected in reserves/MPA (& endemic and keystone species abundance)
	Education/awareness	Educational expenditure (budget %) Literary rate (15-24 yr olds)
	Employment creation	% employment in fisheries/farming/tourism/state jobs
Response	Budget allocations	Year-on-year real growth/reduction trend
	Migration as a livelihood strategy	Migration data by age and direction (with net flow)
	Fostering low scale self-organisation	Emergence of new businesses/activity by category
	Trust	% ethnic/religious balance in government Cronyism (transparency perceptions index)
	Cultural norms	Surveys of conservation/economic culture
	Enforcement deficit	Seizure rates, effective sanctions imposed
	Lack of political will	Reduction of open access resource issues
	Willingness to invest in adaptation	Rule of law
	Lack of social/scientific study	Number by field
	Local participation	Local versus external ownership /leases by area

*(due to flux in policy and institutions, and known data gaps, data sources and level of aggregation are not proposed here but could usefully be agreed at local and national level as a focusing exercise)

5. DISCUSSION

This chapter is used to summarise just some of the key issues raised in earlier chapters through the lens of the DPSIR framework. The DPSIR process is at the same time modified for small tropical islands and then used to propose indicators for conservation and development policy. The discussion here highlights the relevance of the DPSIR framework so far only proposed for use in Mauritius.

DSPIR would appear to hold useful insights for Rodrigues as the two-islands consider joint approaches to development and conservation including MPA and ICZM. A broad application of DPSIR across spatial, temporal and sectoral scales potentially adds insights to levels of complexity relevant to more focused application such as for fisheries in Kenya (Mangi, Roberts et al. 2007). Indicators suggested for Kenya for coral reef fisheries would seem appropriate, with modifications for Rodrigues. However, other variables may be usefully added as suggested to take account of different scales and a wider range of contextual issues feeding into drivers and response options. Rodrigues could usefully be included in a full DPSIR analysis on a national scale to take full account of island and then inter-island pressures that may be considered to be beyond MPA boundaries restricted to certain coastal and marine areas. The indicators here are proposed for discussion only with the aim of encouraging a coordinated approach to process and outcome aspects of policy formulation and measurement across all key aspects of island development and conservation. Indicators here could usefully be refined with the help of resource users such as fishers as part of co-management leading to trade-offs. DPSIR and suggested indicators could help reveal more options for island sustainability related to fishery effort reduction generally (gear-effort-enforcement), and how to create novel solutions fostering social-ecological resilience through facilitation rather than the current reliance on top-down direction.

6. CONCLUSIONS

DPSIR is usefully adapted and applied to island conservation and development management contexts to categorise and find indicators for issues that through their interrelationships may determine options and obstacles to social-ecological resilience. The framework is perhaps more useful at local, immediate scale at the point where the adaptive cycle appears to lose its explanatory value for describing long-term trends.

CHAPTER 8

8.1 Summary

Two main research questions were addressed in this thesis: “are conservation and development compatible goals for Marine Protected Areas in small islands reliant on fisheries and tourism?” (“win-win” scenario), and “do social-ecological resilience concepts clarify related issues of sustainability?” Findings were divided into four main chapters (3-6), each addressing a key objective and followed by a synthesis in chapter 7. Two focal quantitative chapters related to research question 1. Both presented evidence and arguments in favour of MPA, one through a demonstration of evidence of ecological decline based on local ecological knowledge, the other through a determination of tourism user fee potential to fund conservation and create livelihoods. On balance, these two chapters suggested some potential for a “win-win” scenario. Beyond this, notable downside risks emerged in findings from two other qualitative core chapters. One addressed long-term issues of social-ecological resilience at island level through a consideration of the explanatory value of Holling’s Adaptive Cycle (Holling and Gunderson 2002), focusing on societal reorganisation after a 1970’s drought. The second qualitative core chapter focused on conflicts in development and conservation policy relating to a need for alternative incomes for fisher-farmers, and socio-cultural and institutional obstacles to MPA co-management. Indicators for assessing MPA outcomes in island coral reef management contexts were also proposed after Chapter 7’s consideration of findings within a modified version of the Driver-Pressures-State-Impact-Response (DPSIR) policy model.

8.2 CONCLUSIONS

The decline of large predators and other fish species in a remote oceanic location underlines a global trend of marine ecosystem impairment. Degradation may not be halted if one generation of resource users does not inform the next of rate and extent. This “shifting baselines” problem demonstrated here quantitatively for the first time in an island reef fishery underlines this risk of degradation and wider risks as it appears to apply to climate variability and other natural resources on land and sea. Policy-makers also seem to discount degradation. With this in mind, small islands with livelihood options cut by ecosystem goods and services decline may be highly vulnerable to disturbance, such as natural hazards and climate change. Social and ecological thresholds may be passed before people realise, leading to species depletion, more extinctions, and loss of critical ecological functions needed for human well-being in development policy.

Such acute risks need to be addressed in conservation and development policy. Few of the long-term drivers of Rodrigues' forest soil, water and lagoon degradation raised in this study have ever been resolved, despite official warnings from the late 1800s onward of dire consequences for the island's viability. Degradation of the island appears to have been almost linear, dating back to comparatively recent settlement, rather than cyclical as suggested by Holling's conceptual Adaptive Cycle model for analysing phases of collapse followed by recovery in social-ecological systems. Colonial and then distant national government based on the main island of Mauritius saw Rodrigues for what it could provide, and then increasingly as a liability. Regional Autonomy in 2001 in theory gave Rodrigues' local politicians a chance to break with past trends and improve prospects for conservation and development.

Planned Marine and Coastal Protected Areas would appear to be a valid option for addressing Rodrigues problems. In practice, Rodrigues' own margin for manoeuvre is limited by its constrained powers, capacity and budget. This study shows that MPA-related tourism could generate fees to fund conservation, but subject to the considerable challenge of marketing degraded remote islands. Local fishers' perceptions of ecological decline evident in shifting baselines suggest they and tourists may benefit from protection of species of mutual interest. However, MPA may be so tightly woven into headlong development, including tourism, for cutting regional dependence on central budgets that through location, management and personal interests they do not meet intended social or ecological goals – even if clearly stated.

Tourism as a motor of development on such small islands risks adding to acute pressures on already stressed natural resources. Preliminary boundaries of the main MPA in Rodrigues were drawn up arbitrarily by donors and other outsiders for reasons few could recall beyond central government priorities shifting from conservation to development. Feedbacks from development uncoordinated across sectors on land and sea pose rising risks at island level to potential for conservation at MPA scale.

Scale issues in this study go to the root of questions over the compatibility of conservation and development goals in small islands in resilience terms. The devastating 1970's drought in Rodrigues illustrated how the impacts of local degradation may be exacerbated by external natural hazards (drought and cyclones), but also external (national) policy responses ensuring degradation is perpetuated (e.g. fishing incentives). Just as Rodriguans relied on migration to find new livelihoods as their island's economy collapsed into dependence on Mauritius during and after the 1970's drought, so tourism development now shows how Rodrigues still depends on

capital inputs from higher scales, with imports reflecting risks of ecological degradation being passed up to scales beyond local borders (e.g. water for food produce, fish). Rodrigues' plans for desalination and new power plants illustrate its development limits particularly in terms of related agriculture and tourism, and consumer-lifestyles.

Overall Rodrigues within the Republic of Mauritius typifies the so-called "twin island" problem, describing the secondary status of marginal islands-within-islands. A lack of shared vision between local and central island government, with ethnic tensions reflected in inter-island discussion, typifies this example. Rodrigues risks being left behind once again in wider Mauritius' latest economic adjustment (towards services), with local livelihoods remaining linked to depletion of remaining natural resources. There is a risk that even good policies to end this will be rejected by both sides, fuelled partly by Rodrigues' local animosity to outsider interference and domination of development style – and a Mauritian view that such choosiness is a luxury paid for by national taxpayers.

Greater trust is needed as a precondition for more adaptive governance from national down to MPA co-management level. Fishers and farmers are aware they need to stop degradation, but need reassurance over livelihood, benefit and enforcement issues, particularly when MPA are announced with big budgets and jeeps, but small prior efforts to enforce even basic fishery regulations or stop blatant corruption. A bottom-up management approach may even be resisted as coercion in a top-down culture in which resource users are so adapted to flouting and circumventing rules, with effectively open access to resources on land and sea. Fishers' and farmers expectations and knowledge therefore need to be better understood as they make difficult adjustments to their livelihoods. MPA are rarely built on scientific criteria alone,

particularly under planned co-management. An education strategy could help address school failure rates, build less damaging livelihood options and raise positive elements of local Creole culture. Together this could help address the wider root problem of a historically low conservation ethic, and losses of social memory on the island.

8.2.1. Key points

Conclusions are given in more detail by chapter but overall remain subject to a state of flux and uncertainty in policy in Rodrigues. However, conservation and development cannot be considered sustainable simply because MPA mitigate some of the likely impacts of planned development while underlying island level drivers and external variables are treated separately. Ultimately, success in sustainable development may be claimed at any scale if arbitrary lines are drawn across points at which the paradigm becomes weak – presenting local benefits while ignoring flows of social, economic and ecological capital up and down scales. Winners and losers in MPA or related policy for conservation and development may be perceived simultaneously, but at different scales, complicating policy trade-offs across scales – in this case at inter-island level. The local knowledge of fishers and other resource users may contain pointers to planning to ensure MPA build social-ecological resilience in other data-poor islands in Africa, where funds for wider science are limited but degradation is rapid.

8.2.2. Implications for small islands

The marginality of some recently settled islands and their frequent lack of control over external variables underlines island fragility in economic and ecological terms. MPA success and failure in reconciling conservation and development may be highly specific

to location and management style and cannot be guaranteed. Historical cycles of degradation and recovery provide pointers to managing MPA. Island-level MPA may serve as an appropriate scale to avoid clashes in development and conservation. Development options based on linking biodiversity to tourism may quickly expose shortcomings in island resource bases. Setting multiple goals for MPA to foster sustainable development could cut their ability to meet either conservation or development. MPA in stressed areas of questionable ecological significance may not deliver durable benefits in ecological terms. Local acceptance of policies such as MPA from various constituencies such as fishers may still depend on degrees of economic benefits or resources they secure, which may be uncertain and unpredictable. Tourist user fees may raise MPA revenue in the remotest of islands, but the marketing challenge may be considerable and benefits of tourism qualified when viewed in terms of capital inputs and outputs across scales. Development options less related to MPA-related tourism may be needed. Local knowledge could be used more, to foster adaptive MPA management of fisheries and other natural resources and avoid MPA failure seen elsewhere. Water stress and mismanagement may become a direct cause of failure of MPA as livelihood options in small islands are cut and degradation restarts. Long timeframes for MPA benefits to be perceived by fishers may create impatience, raising the importance of compensation, livelihoods and migration. Climate change may shift “win-win” policy scenarios related to MPA conservation and development to “lose-lose”. Migration may then be a final arbiter of sustainability. Government decisions to limit human capital flow raise potential issues of social and ethnic tension.

8.3 Research limitations

Research limitations are indicated by chapter. On a general level it was not possible to investigate in more depth linkages between fishing and farming activity. MPA awareness was low, and boundary lines unclear, restricting scope for a more focal comparison of fisher, farmer and tourist perspectives. There was a lack of prior natural science studies indicative of issue relating to ecological resilience. Field studies coincided with a political crisis ending with a change of island leadership. Research was conducted in an atmosphere of tension, politicisation (fisheries, MPA and other related issues) and insecurity for island administration staff. Prolonged delays in MPA planning, a lack of project staff and low awareness of MPA raised the need for a contextual island-level research approach. An attempt was made both in objectives and in fieldwork to complete research of direct policy relevance to MPA planning in Rodrigues. Local pressure to accept pay and re-direction of study scope was rejected and the study proceeded with backing from the Prime Minister's office. It was necessary to interview fishers and tourists in an order related to such research realities on the ground, including a collapse in tourism, an unprecedented outbreak of dengue fever and progress with Creole language learning. Such research issues are usual in development contexts (Bulmer and Warwick 1993; Bunce, Townsley et al. 2000).

8.4. Contribution to knowledge

The primary original research contribution of this thesis lies in explorations of recent historical ecology. This thesis provides the first quantitative demonstration of the phenomenon of shifting baselines in coral reef island fisheries, and also in an MPA planning context. Such studies in data poor islands may be critical to policy formulation,

winning support and demonstrating success in a way understandable to resource users. They also provide a basis for global comparisons if repeated worldwide, in similar and differing contexts. Otherwise, chapters in this thesis:

- 1) Proposed limitations to the conceptual Adaptive Cycle used for considering social and ecological change in resilience terms (Gunderson and Holling 2002).
- 2) Outlined potential for MPA user fees where it was expected to be minimal in marginal small islands (Depondt and Green 2006).
- 3) Underlined migration and other cross-scale capital flows as key determinants of sustainability at inter-island level in small states using MPA (Neumann 2004).
- 4) Related water stress (Payet 2006) closely to prospects for MPA development.
- 5) Proposed a modified version of the DPSIR (Driver-Pressures-State-Impact-Response) framework (Mangi, Roberts et al. 2007) for use in developing indicators to guide MPA policy for small island conservation and development.

8.5. Beneficiaries

Papers from this research were published in international policy journals and sent to the local hosting marine science research centre for submitting to high levels of government (Ministries and Prime Minister's Office). MPA advisors to Rodrigues acknowledged the usefulness of published findings at a critical time in policy planning. This thesis will be submitted to Rodrigues' main public library. Post doctoral workshops were arranged in Rodrigues by the author in 2008 as part of post-doctoral research aimed at understanding links in resilience terms between coastal ecosystem services and poverty alleviation. Some other future research directions are indicated below.

8.6. Future studies

Future research could be more focused on local MPA issues in Rodrigues now that planning is moving ahead. The importance of understanding the environmental behaviour of fisher-farmers (Gelcich 2005) needs more study in the context of how they perceive their own resilience. Such studies could be combined with trade-off Multi-Criteria Analysis (Brown, Adger et al. 2001) to promote policy under a cross-scale co-managed MPA regime. It would be useful to relate how shifting baselines in fishers' perceptions of past ecological state relate to their perceptions of MPA policy at planning and then outcome stages? Shifting baselines studies would also benefit from global comparisons across ecosystems types, regions and cultures. Recently-settled islands, such as Rodrigues and Galapagos, present an opportunity for comparative study on local attitudes to conservation compared to longer-standing island societies with stronger taboo or other forms of self-organising conservation. Other studies in terms of practical application of MPA policy in Rodrigues are needed on most socioeconomic and ecological levels, including the relevance of migration in determining a "sustainable" level of population, and how winners and losers emerge from MPA across scales. Comparative studies between twin-islands states such as Mauritius-Rodrigues and Trinidad-Tobago may hold useful policy lessons. Links between social and ecological resilience also need further study, to further clarify the explanatory value of Hollings Adaptive Cycle. Likewise, links between climate change and resilience in coastal communities in poor countries need to be understood.

Appendices

Appendix 1: Sample interview transcripts: Abridged version highlighting key issues

01.12.05 Former politician (Minister for Rodrigues), ex-Catholic priest, current French Consul, Head of Ecotourism "Green Gites" organisation.

Interviewee: Benoit Jolicoeur

Location: Residence Foulsafat, Auberge/Table d'Hôte, Jean-Tac, Rodrigues

Interview type: Exploratory / SSI

Language : French

INTROetc

Notes – Former priest, like Island Chief Serge Clair. Helpful but unlikely to supply data. Jolicoeur is very well-known locally and in Mauritius and attended the Assise du Tourisme meeting in Port Louis in Feb with Serge Clair, Laval and Francoise Baptiste, Maxy Andre, Wong So (airport s/holder etc), Pierre Argo (photographer on Baptiste's book, Air Mauritius brochure), Departmental Head tourism, fisheries and environment Thomas Genave, D-H Jugoo. Inner circle. Rodrigues in 1960, left to work in Mauritius, and then studies in Paris at Angers, until 1987. Returned as journalist up to 1991, politics up to 2000. Invited by the British government to study autonomy and local government in Orkney.

Radical ecological change – life BEFORE and AFTER 1970s drought

BJ: Let me first say that when I talk about Rodrigues I talk about a 'BEFORE' and an 'AFTER'. The 'before' is before the 1970s, when Rodrigues produced a lot more..... Farming and fishing. When the land was much farmed, when there were not so many people working for the government. When people did not struggle to make a living and relied on the land to be able to live. And if they did not work they did not live. It was a traditional economy in which you counted on produce from the land, sea and husbandry. And if you didn't have that you didn't live. We exported a lot to Mauritius. But, then came the great drought in the 1970s. I think that greatly affected Rodrigues. There was no rain for more than five years. People had to walk a lot for water, the crops were left, and the cows had to climb into the hills to find grass. The cows died. So it was catastrophic. To deal with it, the government at the time employed a massive amount of people in public service to do terracing work, not very productive work. But people at that time had, every 15 days or at the end of the month, a salary or food produce – maize, oil – they could live. They were paid or given food. Then, after a time, the government formalised their status by employing them. After a while, this part-time work for a specific reason became full-time.

Employment shift – farms abandoned

BJ: From then on, these people who had made a living from agriculture as they had a hard time living saw their future life in public functions. That further removed Rodriguans from the land.

1970s drought destroys food security- boosts rice import dependency

BJ: At that point, dietary habits changed. Then, every day, we ate rice, sweet potato and manioc. But with dietary habits we changed to rice. Before we ate what we produced, maize, manioc, sweet potato. After this drought we changed habits, stopped eating what we had produced, and imported rice came to replace the maize that we ate.

Change of mentality – subsistence work ethic disappears

MPB: (rising food imports in drought)... destabilised the balance of payments?

BJ: Exactly. That is why I am telling you there was a before and an afterwards. And after there was a change of mentality so people instead of working hard wanted a salary and that kind of thing ... you had easy money, didn't need to spend much time in the field. You could come back from a government job early enough to still have time. You did not have to work all day to get your money, to eat.

Cattlewalk – (collective action) stray cows in 1970s wreck farmland

BJ: The desertification of the land, the leaving of the land, and as I said the cows went up into the hills. The cows were kept more along the coast but they went up and the cows were everywhere - they grazed and wrecked the whole environment.

Post-drought reforestation policy, cow management fails

BJ: There was a tree re-planting effort - fencing the areas. The FED helped. Encouraging people to intensify rearing – which did not work unfortunately -

Donor livestock policies rejected

BJ: People were used to letting animals wander about and then you had to put them in a stable, get grass for them, plant pasture. It is still a new way of doing things so people preferred to get in with the government as it was more easy than starting a business where they would have to make such an effort.

1970s impact on fisheries

Drought spurs lagoon fishing effort

BJ: As the land was abandoned, some went into government and some went to the sea to fish a lot more. And then to crown it all, to accentuate it all, the arrival of the Bad Weather Allowance – 'The fishermen, they fish for Bad Weather Allowance'.

MPB: ... and it encouraged over-fishing?

BJ: Yes.

MPB: And octopus fishing went up at the same time?

BJ: Yes.

Decision-making and inter-island power

Inter-island differences drive autonomy push

BJ: To begin with, it is a fact that Mauritius and Rodrigues are distant, with different histories, realities, people... and the type of development suited to Mauritius is not necessarily so for Rodrigues ... develop in a way suited to Rodrigues with Rodriguans participating fully in the elaboration, formulation and implementation of projects affecting Rodrigues ...give Rodriguans a chance to decide what they could do for the country and how they could feel responsible for their future.

Autonomy granted willingly

BJ: The Mauritian government understood what we wanted ...No. It was not extracted. When the law was voted in parliament, all the parliamentarians, the opposition and the government, voted in favour.

Decision-making: Autonomy act unclear in its division of responsibilities

BJ: It's basically clear.

MPB: It's clear?

BJ: It's basically clear. But after three years of autonomy, it's not certain it's clear to everyone. In practice, much more difficult and arduous.

Autonomy on paper has to be reality

BJ: It is a success, but I would say it is a struggle which will continue. We have to conquer, acquire and fulfil this autonomy. It's not good enough to have on paper, you have to have it in law but it has to be real. And on that point the battle is not won.

Define autonomy success – more effective power

BJ: When Rodriguans are more able to achieve everything the law allows them, more effectively responsible in practice in different areas - environment, agriculture, fisheries, development and all that – and when they produce more. Then the economy can really take off with Rodriguans as the main economic actors.

Small island limits to economy

Economy of scale- niche markets needed

BJ: It's true that we have a difficult economy. We have a restricted market for selling products and the challenge is to identify products particular to Rodrigues. For example, honey. We should full ahead with that to export, to sell it, with a label so that Rodrigues will be known for its honey. We need to find a few products like that, honey, chillies – I don't know – food processing .. and develop them more.

Mixed economy but IT needed – island constraints

BJ: I think these three – agriculture, fisheries, artisan crafts, food production, tourism – should all go together. But we should go for IT to have e-commerce. IT should be another pillar of the economy.

Job creation policy slow

MPB: So now the challenge is to find people jobs outside of the government?

BJ: It is being talked about. In reality ... (laughing)

Perception of SIDPR

BJ: It means we need stable, productive jobs which support the island's economy. So that we can profit from our resources.

MPA: enforcement, jobs and decision issues

Perception of MPA – good

BJ: I think it's a good idea – it's good because I understand it will regenerate the lagoon and give life back to the sea. There is overexploitation of the lagoon at the moment so we must give the time and means for it to recover to ensure the future.

MPA Enforcement unlikely, degree of local management participation?

BJ: What means will be available for people to really take ownership of this project? There is often a contradiction between what people say they are going to do and the practice. The fishers will say we must give the sea a rest – it has entered into their consciousness, way of talking, words – but in practice the same people will go and fish and do damage and all that. Already, illegal fishing cannot be controlled ..

MPA capable of overcoming enforcement issues?

BJ: For years, Rodrigues has needed a real control over the lagoon. That is the current position. So I'll ask you a question. When it comes to the Marine Park, how are we going to control, efficiently, these places that are going to be chosen for the Marine Park? How are we going to make it so the fishermen, themselves, the population take ownership?

Decision-making: Top-down vs: bottom-up for MPA

BJ: From above! That's the work the government has to do and I don't how they will go about it. BJ: The other problem - with contradictions – is that so that ownership can be done properly, with people feeling a part of it, you need to have alternatives (living).

No alternative jobs for fishermen

You can't say to people that they can't fish there unless they have an alternative place to fish or another economic activity.

Fishing damage – seine illegal fishing year-round //////////////////////////////////////SAMPLE ENDS

Appendix 2 a): Sample fisher's survey (Chapter 4) relating to perceptions of issues raised in all chapters but specifically shifting baselines



**NATURAL
ENVIRONMENT
RESEARCH COUNCIL**



FISHERMEN'S PERCEPTIONS SURVEY Researcher: **Matthew Bunce**

Date: - 06 Time: Location: Nearest Fish Landing Station:

1. Are you a fisherman? Y/N 2. Where is your home? _____ 3. Age _____
4. How many years have you fished around Rodrigues? ____ yrs
5. How do you normally fish?

a. Gear	Line	Traps	Seine	Harpoon / rod
b. Extent	FT	PT	Seine season only	Other
c. Main target	Fish	Octopus	Shells/Crustaceans	other
d. Usual area	Lagoon	Off-lag(reef)	Off-lagoon (seas)	Banks -St.Brandon
	North	South	West	East

e. Indicate fishing range:
name / map code IF
possible

Permit or card: Lagoon () Off-lagoon () Both () Seine () Too old () None ()

6. How would you describe the state of fish stocks around Rodrigues? Good/OK/Bad

	Abundance Under-fished	Assez et stable Fully exploited	Diminué Over-fished	Tres diminué V. over-fished
Lagoon				
Off-lag				

7. Where have you fished the most since starting fishing?
General area, name or give indication using grid map: _____

8. Indicate any areas that you think are much more depleted than others? Y/N/?
Give map codes/names if possible but otherwise give general area and direction.

Area	North	South	East	West
Lagoon				
Off-lag.				

9. Identify fished species that have become absent or very rare, in the Lagoon or Outside (specify) since you started fishing remember. (Fill table*. Comment on sharks/rays).

Species (FRTS)	Lagoon	Off-lagoon	Yrs

10. Grouper (shifting baseline)

Have you ever caught a White-spotted grouper V. Plate? (<i>Epinephelus multinotatus</i>)	Y/N
If yes, state size of the largest of this fish species you ever caught	kg cm
In which year did you catch it? (five year time block at least)	yr
Where was it caught? (Coast, lagoon-passes, off-lagoon)	
How did you catch it? (line, trap, harpoon, seine)	
How many did you catch in your best ever best day?	
Give approximate year (and month if you remember)	m yr
Where were they caught? (Indicate bearing and zone only if possible)	NSEW

11. Does the lagoon yield enough fish for Rodriguans to eat fish regularly? Y/N/?
12. Do you usually fish further from shore now than when you started fishing? Y/N/?
13. Will fishermen have to invest in offshore boats and motors to survive in future? Y/N/?
14. Do you own a boat and a motor? (Tick which and , give details) Y/N/?
First boat (len.____) purchase yr ____ c. 1st outboard purchase yr ____hp ____
Most recent (len ____) purchase yr ____ d. Total hp engines owned now ____

15. What human or natural factors, on land or sea, have contributed most to the lack of fish and coral since you started fishing? Give the five most important (prioritise if possible):
 1. _____ 2. _____ 3. _____ 4. _____ 5. _____
16. Has there been a time (half decade) which radically changed Rodriguans' ability to fish AND farm in balance with nature? If so, when? _____
 When was Rodrigues best period decade (part decade) of fishing? _____
 When would you say the lagoon fishery started to decline? (specific) _____
 When do you remember the coral being the healthiest compared to now? _____
17. Suggest 5 steps needed to protect the future of the lagoon fishery (in priority order).
 1. _____ 2. _____ 3. _____ 4. _____ 5. _____

Most of the following questions require a Y/N answer. If really unsure, say Don't Know (?)

18. When real fishermen respect fishing laws, illegal fishers benefit the most Y/N/?
19. Over-fishing and overgrazing part of the same problem? If yes, why? _____ Y/N/?
20. Have fisheries reserves ever been well-enforced and improved fishing? If so, when? _____ Y/N/?
21. Are existing marine reserves enforced? Y/N/?
22. Does Rodrigues need any more reserves or marine parks? Who should enforce them? _____ Y/N/?
23. Do tourist sports at sea, inc diving, disturb fishing activities? If so, which and why? _____ Y/N/?
24. Would there still be enough fresh local fish for Rodriguans if tourism expanded? Y/N/?
25. Would it bother you if tourists were allowed to dive/snorkel in marine reserves or parks where your fishing is partly or completely banned? If yes, why? _____ Y/N/?
26. Could marine tourism benefit fishermen in any way? How (3) _____ Y/N/?
27. How do you earn most of your income (up to three in priority order)?
 1. _____ / 2. _____ / 3. _____
28. Rank the importance (1=top) of the following for the future of Rodrigues
 Off-shore fishing (), farming (), tourism, other () _____
 Young fishers: what work attracts you beyond fishing? _____ (if same/more income)
29. Do you farm Animals () Crops () for sale (tick)? Y/N/?
 Indicate plans to raise output (+), cut (-) or keep same (=) for cows () Pigs () sheep/goats ()
 maize () haricots (), onions () table veg (), fruit () nuts (), limes () chilli () garlic ().
30. Do you usually get enough water (pipe) for your own needs ? (m/yr _____) Y/N/?
 Connected to water pipeline network? Y/N
31. Does the lack of water stop you farming as much as you would like? Y/N/?
32. Do you remember any time when people fished more for food because of droughts killing crops and/or livestock? When? _____ (usual months or period of years) Y/N/?
33. Do fishermen generally agree with advice about the sea from scientists? Y/N/?
34. Does the RRA involve fishermen enough in decisions that affect fishing? Y/N/?
35. Does Mauritius treat Rodrigues fairly when making big fishing policy decisions? Y/N/?
36. Does Rodrigues need even more autonomy? Why? _____ Y/N/?
37. Should coral, fish and mangroves be protected for future generations Y/N/?

38. Answer the following questions and indicate if the trend is bad for fishing overall (B):

- a. Does the island have more trees now than when you were young? Y/N/?-B
- b. Have droughts become more severe over your lifetime? Y/N/?-B
- c. Have cyclones patterns changed? Tick if less frequent ___ stronger ___ drier ___ Y/N/?-B
- d. Overall, has the lagoon got shallower since you started fishing? Y/N/?-B
Reasons:
- e. Generally, is the sea-bed rising due to sand build-up, even far from the shore? Y/N/?-B
How much less of your punting pole goes into the water due to this rise? _____ ft
Since when _____ Reason:
- f. Do you remember a time when a lot of coral died and fish floated on surface? Y/N/?-B
Reason:

QUESTION 6: TABLE FOR REPORTED REDUCED OR ABSENT SPECIES

Fishers asked to name fish that are rare or absent, not those that are just smaller/fewer

Species (FRTS)	L/O	C	Main Reasons	Yrs
FISH				
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.			Etc.....	
OTHERS – Sharks, rays shellfish, tortoises etc				

Interview sample by area (completed)

Age	N	S	W	E	Total	Done (tick)
20-29	11	11	5	3	30	
30-49	15	13	6	4	38	
50+	10	8	4	3	25	
Total	36	32	15	10	93	

Interview sample by location (cross-off completed)

ZONE	2	5	6	11	12	13	14
FLS	N Bay	Mathurin	GB	Plain Corail	Riviere Cocos	PSE	Graviers
				Petite Butte	Tamarin	Port SE	
				Dans Cocos	Riviere Cocos	Mourouk	
				Pointe l'Herbe			
	4	3	4	8	4	4	3
	6	5	4	10	5	4	4
	4	3	3	7	3	2	3
	14	11	11	25	12	10	10

Appendix 2 b): Tourist questionnaire used in elicitation of willing-to-pay survey, with sample spreadsheet of qualitative comments



L'HOMME ET LA MER 2005/6

Bonjour. Nous effectuons un sondage pour mieux comprendre les liens entre les activités humaines et l'environnement de Rodrigues. 10-15 minutes de votre temps contribuera à la formulation de recommandations visant la gestion des ressources de cette île.

A.1 Êtes-vous résident de Rodrigues? (cochez si 'non')

Oui **ARRETEZ ICI (sondage est pour visiteurs)**
Non

A.2 Quelle est votre pays de résidence. Cochez une case

Maurice (mais pas Rodrigues) France
Réunion Autre (veuillez préciser) -

A.3 Vous passez combien de jours à Rodrigues ?

1-2 jours 5-6 jours 11-14 jours
3-4 jours 7-10 jours 15+ jours

A.4 Combien de fois avez-vous visité Rodrigues, y compris ce séjour? (Cochez une case)

1ère visite 2 3-4 5-9 10+

A.5 Lisez bien les instructions pour cette question : Classez les 5 raisons principales de votre séjour à Rodrigues. Écrivez 1, 2, 3, 4 ou 5 selon importance (1 = la plus importante). Utilisez chaque numéro qu'une seule fois. Ne cochez pas avec un 'X'.

- | | |
|-------------------------------------|---------------------------------------|
| 1. Affaires/Mission Officielle | 9. La pêche au gros |
| 2. En visite chez des parents/amis | 10. La cuisine |
| 3. Plages/Baignade/Soleil | 11. Plongée en apnée/snorkel ou SCUBA |
| 4. La beauté naturelle | 12. La sécurité (criminalité faible) |
| 5. La culture Kreol, les Rodriguais | 13. Curiosité/Nouveauté |
| 6. Isolement | 14. Promenade à pied/vélo T-T |
| 7. Le côté romanesque / amour | 16. Achats hors taxes |
| 8. Flores et faunes endémiques | 15. Autre – veuillez préciser: |

A.6 Votre impression globale de la santé de l'environnement de Rodrigues ?

1. Très bon 2. Bon 3. Pas mauvais 4. Pas bon 5. Mauvais 6. Très mauvais

A.7 Est-ce que la mer et la côte sont des éléments indispensables de votre séjour? Cochez

1. Très important 2. Souhaitable 3. Pas essentiel 4. Aucune importance

A.8 Vous avez fait des activités ou excursions en mer/au lagon/ récif/flots? Cochez une

1.	Oui	() ALLER A LA PARTIE 'B'	2.	Non	() ALLEZ A LA PARTIE 'C'
----	-----	---------------------------	----	-----	---------------------------

PARTIE B – ACTIVITES EN MER/ LAGON/ RECIF/ ILES SEULEMENT

B.1 Quelles activités avez-vous fait au lagon ? Classez jusqu'à 5 activités en mer que vous avez faites pendant votre visite. Ecrivez 1, 2, 3, 4 ou 5 selon importance - '1' est la plus importante. Utilisez chaque numéro une seule fois.

- | | |
|--------------------------|---|
| 1. La voile | 8. Plongée sous-marine |
| 2. Surfing | 9. Plongée en apnée (snorkel) |
| 3. Kite-surfing | 10. Natation |
| 4. Planche à voile | 11. Excursion aux îles/plages en bateaux |
| 5. Kayaking/Canoeing | 12. Excursion avec pêcheur artisanal |
| 6. Pêche au gros | 13. Pêche à l'ourite/ Observation d'ourite |
| 7. Bateaux fond-de-verre | 15. Autre/pas d'activités (veuillez préciser) |

B.2 Choisissez une description de votre expérience du lagon/le récif/les îles. (Cochez une)

- | | |
|---------------------|--|
| 1. Mieux que prévu | 3. Pire que prévu |
| 2. Comme j'ai prévu | 4. Pas de préconceptions/ Je ne sais pas |

B.3 Avez vous déjà visité d'autres milieux marins tropicaux?

- | | | |
|--------|---------------|--------|
| 1. Oui | Préciser où : | 2. Non |
|--------|---------------|--------|

B.4 Cochez la note que vous donneriez aux lagon et récifs de Rodrigues en comparaison avec vos expériences de lagons et récifs ailleurs? (1) est la meilleure et (5) la plus basse

1 très bon	2	3	4	5 très mauvais
------------	---	---	---	----------------

B.5 Qu'est ce que vous a fait le plus plaisir lors de votre visite en mer/ au lagon/récif/île?

- | | |
|----|--|
| 1. | |
| 2. | |

PARTIE C - PLONGEURS OU APNEES/ TUBA-MASQUE-PALMES seulement

C.1 Combien de fois avez-vous fait une plongée (bouteille ou apnée/tuba) dans votre vie?

1. Plongées ____ 2. Apnées ____ 3. Ne plonge pas () **ALLER A LA PARTIE D**

C.2 Indiquez VOTRE IMPRESSION de la santé des coraux observés lors de votre dernière plongée ici à Rodrigues

- | | | |
|--------------------------|------------------|----------------------|
| 1. Très bonne santé | 4. Plutôt malade | 7. Morts |
| 2. Bonne santé | 5. Malade | 8. Je ne sais pas |
| 3. Plutôt en bonne santé | 6. Très malade | 9. Autre (spécifier) |

C.3 Disons que les poissons, les coraux et les eaux restaient comme vous avez observés lors de votre cette dernière plongée à Rodrigues. Indiquez le prix maximum que vous serez disposer à payer pour une telle expérience? (Disons 36 Roupies = 1 euro)

- | | |
|---------------------------------|------------------------------------|
| 1. Le prix que j'ai payé | 5. 10 euro en plus que j'ai payé |
| 2. 1 euro en plus que j'ai payé | 6. 25 euro en plus ... |
| 3. 3 euro en plus ... | 7. 50 euro en plus ... |
| 4. 5 euro en plus ... | 8. Moins que le prix que j'ai payé |

>>Disons que les plongeurs et les snorkellers sont requis de contribuer à un fonds consacré à la protection du corail/poissons et tortues. Tous les utilisateurs payeraient.<<

C.4 Est-ce que vous seriez d'accord en principe de payer une somme d'argent *en sus* des autres charges de plongées pour la protection de l'environnement marin à Rodrigues?

1. Oui 2. Non () SI 'NON' ALLER A LA QUESTION C.8

C.5 Indiquez le supplément, par PERSONNE/PAR JOURNEE, que vous seriez disposé à payer pour avoir accès à un parc / réserve marin, où la pêche serait interdite. Plongeurs bénéficient de poissons/corail plus abondants. Pêcherie dégradée avoisinante puisse rebondir.

- | | | |
|-----------|---------------|---------------------|
| 1. 1 euro | 4. 7 euro | 7. Plus de 20 euro |
| 2. 3 euro | 5. 10 euro | 8. Autre (préciser) |
| 3. 5 euro | 6. 10-20 euro | |

C.6 Si vous avez répondu NON à la question C.6, c'est-à-dire payer pour la protection de l'environnement, veuillez préciser votre raison. *Cocher une case seulement*

- | | |
|--|---------------------------------------|
| 1. Le gouvernement doit couvrir tous les frais | 6. La conservation ne sert à rien |
| 2. Les pêcheurs doivent être responsables | 7. La nature ou Dieu décidera l'issue |
| 3. La plongée/snorkelling n'endommage rien | 8. L'argent sera détourné |
| 4. J'ai déjà assez de fardeaux financiers | 9. Je ne sais pas/refus |
| 5. Les opérateurs du tourisme doivent payer | 10. Autre |

PARTIE D – TOUT LE MONDE REpond.

D.1 Comment avez-vous imaginé Rodrigues avant d'y venir pour la première fois?

1. _____
2. _____

D.2 Qu'est ce qui vous attire le plus à Rodrigues maintenant que vous êtes ici?

1. _____
2. _____

D.3 Dans l'ensemble, étés-vous satisfait de votre séjour/vacance à Rodrigues?

1. Oui 2. No

D.4 Que peut faire Rodrigues pour s'améliorer comme destination ?

1. _____
2. _____
3. _____

D.5 Est-ce que vous pensez que la côte sauvage Est allant de Cotton Baie au Mourouk doit être développée, y compris les petites anses?

1. Oui 2. Non 3. Je ne sais pas

D.6 La santé des milieux terrestres dépend de la santé des milieux marins, et l'inverse. Rodrigues devrait-elle créer un parc terrestre-marin pour protéger son environnement, avec zones définies pour sports, loisirs, la pêche et la conservation? *Tous utilisateurs payeraient un droit d'entrée et bénéficieraient d'une nature durable et visiblement amélioré.*

1. Oui () ALLER D.9 2. Non () ALLER D.8

D.7 Si vous avez dit 'NON' en question D.7, seriez-vous prêt à payer si un tel parc marin-terrestre est accordé le statut de Patrimoine Internationale de l'UNESCO?

1. Oui () ALLER D.9 2. Non () ALLER D.12

D.8 Précisez le montant maximum que vous serez prêt à payer PAR ADULTE/PAR SEMAINE, pour une laissez-passer donnant accès à un tel parc marin-terrestre. *Soyez franc. en prenant en compte vos ressources financières et votre capacité de payer si demandé.*

Montant total PAR SEMAINE/ PAR ADULTE: (Roupies 36 = 1 euro)

D.9 Si vous ÊTES PRETS à payer pour la protection de l'environnement et la création de parcs/réserves marins, indiquez vos raisons principales :

1.

2.

D.10 Si vous N'ÊTES PAS disposé à payer un supplément pour la protection de l'environnement et la création de parcs/réserves, précisez vos raisons principales.

1.

2.

PARTIE E - AUTRES DETAILS

Nous vous prions de nous accorder encore quelques minutes pour la collecte de renseignements généraux. Nous ne demandons pas votre nom - vos réponses seront considérées dans l'anonymat.

E.1 Destination principale de ce séjour/vacance? Cochez une

1. Maurice 2. Rodrigues 3. Réunion 4. Autre (préciser):

E.2 Mode de transport pour venir à Rodrigues?

1. Avion 3. Yacht
2. Bateau 4. Autre

E.3 Comment êtes-vous venu à Rodrigues? Cochez une

1. Seul 3. En famille (enfants) 5. Autre (préciser)
2. En couple 4. En groupe d'amis

E.4 Hébergement à Rodrigues. Si nécessaire cochez plusieurs avec numéro 1-3

1. Pointe Venus 4. Escales Vacances 7. Famille/Amis – ou?
2. Cotton Baie 5. Auberge - lequel? 8. Autres - préciser :
3. Mourouk Ebony 6. Gîte – lequel?

E.5 Combien de plats de poissons/ourites avez-vous mangé (personne par jour) ?

- | | | | | |
|---------|-----------------|------------|------------|---------------|
| Poisson | 1. Un par jour | 2. 2 /jour | 3. 3 /jour | 4. En plus... |
| Ourite | 5. Une par jour | 6. 2 /jour | 7. 3/jour | 8. En plus... |

E.6 Profil démographique – (répondez pour vous-même, pas toute la famille/groupe)

- | | | |
|-------------|--------------------------------------|---|
| Sexe | Age | Statut prof. |
| Masculin | 1. Moins de 25 4.. 45-60 | 1.Salarié 4.Étudiant |
| Féminin | 2. 25-35 5. 60+ | 2.A ton compte 5.Autre |
| | 3. 35-45 | 3.Retraité |

E.7 Education (cochez une case pour vous-même seulement)

- | | |
|---|---------------------------------|
| 1. J'ai quitté l'école avant le bac/HSC | 4. Université - Licence |
| 2. Baccalauréat/ HSC ou équivalent | 5. Maîtrise/doctorat/équivalent |
| 3. Des cours au collège/faculté | |

E.8 Façon de manger (cochez deux réponses si nécessaire)

- | | |
|--|---------------------------------------|
| 1. Omnivore | 4. Végétarien – mange aucune viande |
| 2. Végétarien – je mange pas le bœuf (à l'Hindu) | 5. Ne mange que des produits Bio |
| 3. Végétarien – mais je mange le poisson/poulet | 6. Je préfère le Bio, mais mange tout |

VOS REPONSES AUX QUESTIONS SUIVANTES SONT INDISPENSABLE A NOTRE ETUDE

E.9 Revenus domestiques. Répondez **OU** en roupies (**PAR MOIS**) **OU** en euros (**PAR AN**) selon votre niveau de salaire. Cette information est importante et traité dans l'anonymat.

1. Euros PAR AN si payé en europe ou selon échelle équivalent

- | | | |
|--------------------------|----------------------------|-------------------------|
| 1. Jusqu' à 10,000 euros | 5. 75,000 to 100,000 euro | 9. Je ne sais pas/refus |
| 2. 25,000 euro ou moins | 6. 100,000 to 125,000 euro | 10 Autre- préciser: |
| 3. 25,000 to 50,000 euro | 7. 125,000 to 150,000 euro | |
| 4. 50,000 to 75,000 euro | 8. Plus de 150,000 euro | |

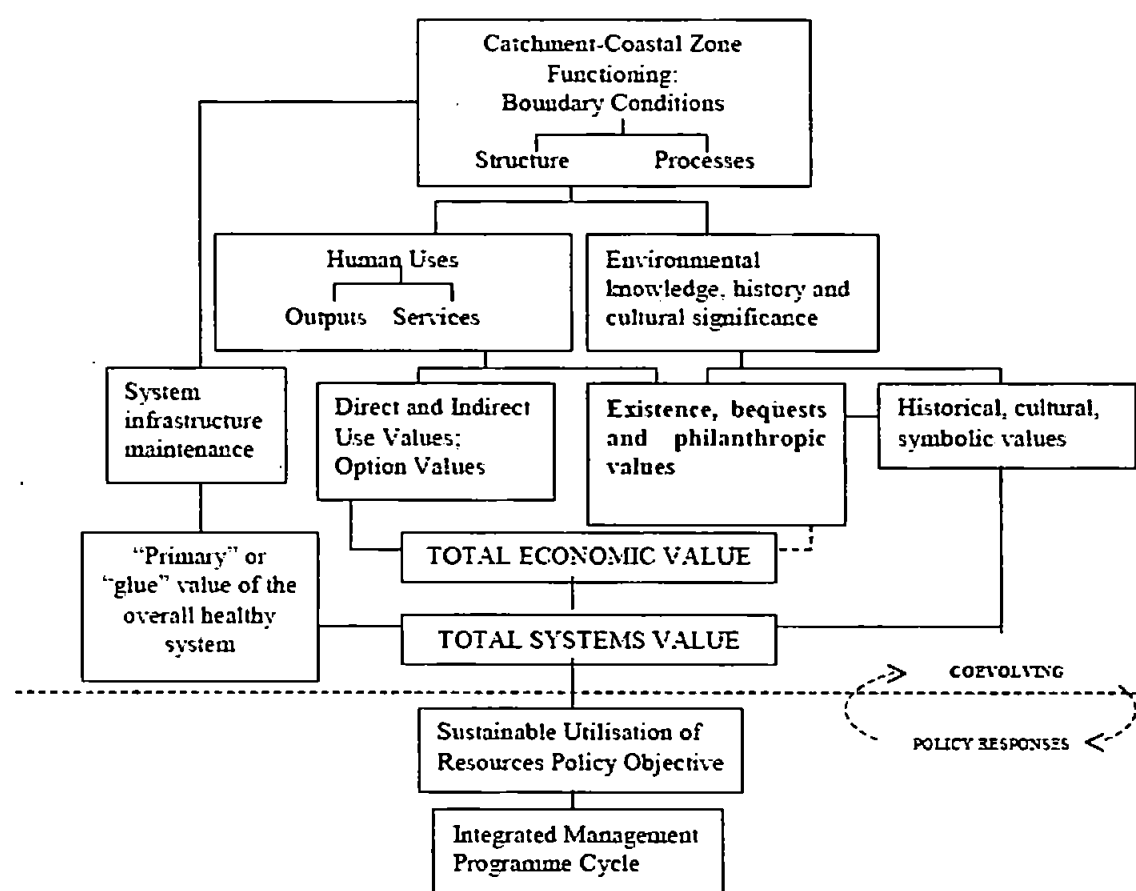
2. Roupies PAR MOIS (plutôt pour ressortissants de la region Maurice/Reunion etc)

- | | | |
|---------------------|------------------|------------------------|
| 1. Jusqu'à Rs 6,000 | 3. 15,000-30,000 | 5. 45,000-100,000 |
| 2. Rs 6,000-15,000 | 4. 30,000-45,000 | 6. 100,000+ (préciser) |

E.10 Vous pensez peut-être revenir à Rodrigues dans le futur? 1. Oui 2. Non

Nous vous remercions de votre collaboration. Bon voyage.

Appendix 4: Illustrative linkage between economic evaluation of the environment (Chapter 5) and Driver-State-Pressure-Impact-Response framework (Chapter 7)



Source: Adapted from Turner *et al.* (2001)

Appendix 5: Representative collage of elite perceptions of key issues relating to social-ecological resilience of Rodrigues island

Migration

(Population)...high (Rodriguan) birth rate...brain drain...island never develops. It is a vicious circle
(Development) Fishing...tourism... unless we engage more, more people will leave (Rodrigues island)
(Crowding) You've got Maurilians who can come and buy land and invest AND Rich people (Mauritians) ... build a second home. What would Rodriguans do except go to Mauritius? (state land as "protection")
(Birth rate high) ... but the population never seems to increase
(Buffer) We are the same state (Mauritius), but who knows! There could be migration controls if they think too many (Rodriguan) people are coming to Mauritius (unemployment, crime, demands)

Perverse fishing incentives

(Livelihood) Cut the BWA in Mauritius and (fishers) get another job – not in Rodrigues!
(Unemployment) Most people do not have jobs so they go to the sea, it is a political problem
(Enforcement) People are getting poorer...want to catch that (illegal fisher)? His children will die of hunger!
(Enforcement) Crooks fish for (fisheries guards) and they share the money
(Open access) The lagoon will decline. It's not the government that will make them stop (but low returns)
(Politics) Government priority is development...keep the (fishers) happy...it is a big, big electoral pool
(Politics) ...recycle fishermen? (into other work) There will be a lot of political issues over that! (MPA issue)

Collapse of farming – farm abandonment

(Shrinkage) ... grave concern that the total area under farm production is decreasing every year
(Subsidy) To restart (farming after 1970s) incentives were ...lacking. We have missed a generation
(Culture) (Youngsters say): "Me? I have been to school! I don't want to work the land"
(Custom) The problem is they (older farmers) are reluctant to change their ways of working
(Imports) There was an invasion of rice... (during and after the drought by) Mauritius traders... (also maize prices were unprofitable)
(Practices) Pests did not used to be (in Rodrigues) because... (people were) using seasonal crops (not year-round cultivation)
(Genetic) If we lose these (acclimatised export) crops (e.g. chilli, red beans, limes) it will be a great loss to the genetic pool

Collapse of farming - land tenure

(Land tenure) Land leasing (90% state-owned) is archaic, should be overturned. It has become a trap (for farming and development)
(Land tenure) Laws are in conflict. Who is responsible? There is a vicious circle turning.
(Land tenure) A lot of land is leased – that has slowed up development (also stops buy-out by Mauritians)
(Commons) ... still a big problem between planters and farmers AND...used to letting animals wander

Water mismanagement

(Trust) They (local leaders can use water (and land) as a political card – and they do (for coercion)

Deforestation

(Commons) The animals were a problem (saplings)... (so we) fenced in the trees (not the animals)
(Endemics) The (quick-drying) endemic trees...when you cut them down you can burn them straight away

Donor projects

(Outsiders) The lack of self-esteem and confidence among Rodriguans in what they prefer plays heavily. Why do Rodriguans normally applaud and give value to foreigners? (Inappropriate donor policy)
(Capacity) In all sectors you see someone heading who knows nothing about it
(Participation) All projects from the outside do not work (examples). The project should be in collaboration with the people, with their own hearts in it. They should define strategy... implement
(Capacity) People are not trained enough in follow up to focus attention and say "Stop!"

Inter-island power shift – rise of strong leader

(Identity) Rodrigues voted against independence... think of themselves as Rodriguan, firstly!
(Culture) Here, Hindus are...majority so (Rodriguans) feel affinity with Reunion, Madagascar, Seychelles

(Patrons) When they look to Reunion (France) ... it looks like they are bypassing Mauritian systems
(Autonomy) Before...we had a grip on Rodrigues. (Then) Mauritians realised Rodriguans are aware of their own power and this was a shock for Mauritians as there were fears of losing the island of Rodrigues

Inter-island power shift – internal power relations

(Collective action) Everything is politicised. It is nothing new that people (Rodriguans) cannot get together.

(Individualism) We (Rodriguans) don't like rules ... if someone goes up the hierarchy we cut them down

(Ethic) It is hard for people to accept rules (on the environment)...don't see the need

(Ethic) ...not that kind of belief system that you see in the Pacific (island fishing communities)

(Insularity) It is an island (Rodrigues) and every family is like an open book which anyone can read and turn the page

(Top-down culture) "Moses" leadership culture: "The priestly mentality says "I am the boss. I am the man who tells you your destiny, plans (it). ...I am god's representative" (Rodrigues)

(Top-down culture) Ideas from lower committees get lost as they are taken higher... people start to speak in French or English (problem of) "Big Men"...people won't say what they think...lose interest

(Ethnicity) Each time Mauritians come up with an idea, Rodriguans say "No!"...("cussedness")

(Trust) You need trust. We are not there to use the baton without the carrot (Marine Protected Area enforcement plans)

Dependence

(Dependence) Rodrigues is like a sick child we are trying to keep alive next to Mauritius

(Dependence) ...sustainability in the long-term is dim. We are 99% dependent on (Mauritius') hand-outs

(Trust) I have the impression that Mauritians gives things to Rodrigues reluctantly

(Ethnicity) Different history...people, different realities... (we need to) develop in a way suited to Rodrigues

(Status/caste) (Hindus and)...Even the Mauritian (Creoles) look down on them! (Rodriguans)

(Marginalisation) ("Creole Malaise" means) Creoles are not at ease ...because they are the poorest and in Indian Mauritius

(Expulsion) If economic stagnation gets worse they will ...think about throwing out Rodriguans

(Region ties) Unity makes strength ... but in small islands why not...a (regional) federal system?

Appendix 6: a) Potential vulnerabilities and impacts from climate change in Rodrigues Island

Intrinsic island vulnerability (Adapted from (Pelling and Uitto 2001))	Climate change risks (Adapted from (Barnett and Adger 2003))
Small size: limited natural resource base, land use competition, intensive land use, close dependence on land	• Coral reefs adversely affected
Insularity and remoteness: High external transport costs, time delays, high costs in accessing external goods, poor information flows, geopolitical weakness	• Shift in species competition and composition
Environmental factors: Small exposed interiors, large coastal area, ecological uniqueness/ fragility, water stress	• Increasingly variable rainfall, intense droughts
Disaster mitigation capacity: Limited hazard forecasting	• Increased cyclonic intensity, larger storm waves
Demographics: Limited human resource base, small total population, rapid population change, diseconomies of scale	• Adverse affects on staple crops due to change in soil moisture, salinity, rainfall
Economic factors: Weak economy, budget dependence, small internal market, dependence on natural resources	• Decline in local food security, partly due to adverse affect of declining crops on fish stocks
	• Coast erosion/climate change affect tourism
	• Potential loss of land due to rising sea level
	• Decline in human health (vector borne disease)

Appendix 6: b) Cross-scale trends: vulnerability and global change, after (Pelling and Uitto 2001)

Global pressure	
<i>Climate change</i>	Food insecurity, water deficits, soil/coast degradation, sugar production at risk in Mauritius
<i>Sea change (level, warming)</i>	Beach erosion and coral bleaching risk to tourism, salt intrusion risk to potable water and cultivable land, risk to coast communities and fishing from wave energy height
<i>Trade (WTO)</i>	Mauritius shift to tertiary sector (inc IT) and use of Asian labour both hit Rodriguan migrants
International linkages	
<i>Cultural</i>	Mauritius as regional economic hub for India / Africa / Europe / Middle East Creole cultural revival and options for more direct links to regional islands/African/Europe Hosting part of regional inter-island games, hosting regional Kreole Festival
<i>Migration</i>	Migration adds (limited) potential for remittances, strengthens economic and cultural ties.
<i>FDI</i>	Low in Rodrigues but growth of tourism/commercial fishing in Mauritius offers scope
<i>Aid flows</i>	Directed through Mauritius – but Rodrigues, sometimes as an “NGO”, can invite and develop aid
<i>Policy</i>	UN Conference on Small Island Developing States (2004) and regional World Tourism Conference (2006) in Mauritius raises national profile. Media exposure of Rodrigues in France
Local events occurring worldwide	
<i>Regionalisation</i>	Poor air access limits options. Mauritian wariness of rival influence, talk of regional federation
<i>Urbanisation</i>	Limited flat land, dispersed population, poor infrastructure, subsistence economy limit trend
<i>Identity politics</i>	Fractionous inter-island politics slow cooperation and development
<i>Internal migration</i>	Eases population pressure, adds to urbanisation (and ethnic tension) in Mauritius, deepens brain drain for creates international links, social memory loss, ageing profile, family breakdown
<i>Environmental degradation</i>	Water stress constrains development. Soil degradation (deforestation, farming practices), climate variability, fishery decline limit economic options. Dependence on Mauritius for budget
<i>Insurance flight</i>	Unknown premium impacts of cyclones but patterns elsewhere suggest risk of insurance flight.

Appendix 7: Distribution (%) of diving tourists' WTP-Marine Park (n=167)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	55	15.7	32.9	32.9
	1	20	5.7	12.0	44.9
	3	32	9.1	19.2	64.1
	5	33	9.4	19.8	83.8
	7	4	1.1	2.4	86.2
	10	17	4.8	10.2	96.4
	10-20	4	1.1	2.4	98.8
	20+	2	.6	1.2	100.0
	Total	167	47.6	100.0	
Missing	n.a.	184	52.4		
Total		351	100.0		

Appendix 8: Distribution (%) of tourists' WTP-Marine and Coastal Protected Area (n=351)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0 euro	74	21.1	21.1	21.1
	1 euro	17	5.1	5.1	26.2
	3	40	11.4	11.4	37.6
	5	36	10.3	10.3	47.9
	7	18	5.1	5.1	53.0
	10	53	15.1	15.1	68.1
	10-20	51	14.5	14.5	82.6
	20 +	61	17.4	17.4	100.0
	Total	351	100.0	100.0	

Appendix 9: Contextual islander perceptions relevant to achieving conservation and development goals linked to Rodrigues' plan for a co-managed MCPA

"Poverty is everywhere and Rodriguans are very indebted. 20 years ago it was lively on pay day but this is no longer the case" **(Regional politician)**

"We do not have (an island carrying capacity assessment). Under our project for poverty we feel there is no solid baseline for poverty assessment" **(Donor)**

We have to get away from a dependency culture to a productive culture **(Regional politician)**

What do we do with all these fishermen? Most people do not have jobs so they go to the sea. You can't tell fishermen to get out of the sea without offering something. **(Regional politician)**

The only way to meet their needs without dying of hunger is to fraud (fishing) ... as long as you have fraud and corruption this will affect our island terribly **(Regional politician)**

They are trying to develop tourism but if you do not have water there is not much you can do about it **(Meteorological office)**

If you talk to the planters, there is only one problem – water, irrigation. The real problem is that they are reluctant to change their ways of working. **(Farm extension worker)**

"The majority of the water is exploited. Sometimes we get big rains but we lose 100% of it. The majority of the water table is exploited – we have 17 boreholes and 3,700 cu m available daily. The daily requirement is 9,000. Now we get 5,000" **(Government water official)**

Developing all these – off-shore fisheries, hotels – I don't see anyone thinking about conservation. In the end it is not about how you link projects to get them to work. What we need is for people to work together rather than: "you do this side and the others do their side" **(MPA project official)**

The government's priority is a development goal...and to make sure that the fishermen are happy because they have great power...a great part of the population is fishing. It is a big electoral pool" **(NGO)**

The idea of conservation has to be anchored in (people) and the rangers. We cannot just pass laws and throw it at them. It has to be a project from below...we cannot just be there with rifles and batons...to use the baton without the carrot...but we cannot be everywhere. It has to be a communal effort. **(Enforcement)**

There need to be community-led schemes but the government is not really geared up for that kind of thing...it (central government) likes to control...particularly what it does in Rodrigues **(NGO)**

Usually a government officer takes ideas to bigger committees. Those guys just say we'll look at it later and it gets lost. People lose interest, and when they lose interest it is hard to get it back. That's a lesson for the MPA. **(Forestry)**

"The problem is that instead of trying to solve the problem on the land you try to solve it in the sea" **(Forestry)**

For tourism?: "There is no policy. There is no marketing. There is no branding." **(Tourism operator and government advisor)**

Q: What if the fishermen's wants do not match those of conservation and development?

A: "We will get compliance" **(MPA project official)**

Appendix 10: Island predicament: recorded interview (2006) with Rodrigues' Regional Assembly leader (JR) shortly before his appointment in a snap election

Commons issues

JR: It is difficult for people to accept rules here ... They do not see the importance of rules. Maybe there is not enough communication about informing, what the advantages will be, why it is necessary to protect the environment, of not engaging in destroying things that protected, rare species of trees, plants etc. They do not see the need. Rodrigues has always been very interactive with the environment – fishing, farming, agriculture – everything was natural here some 30 or 50 years ago even houses were made of wood or thatch - all sorts of natural materials ... What is not within their home could be destroyed, could be taken.

Fishing

JR: People stopped sharing because of scarcity (which) led to increased illegal fishing. Fish may be sold on the black market because the legal ways do not provide enough fish for consumption so people are forced to. There are people who are permanently fishing illegally. This is their profession! If they go fishing legally, and place their traps and fish with line they get nothing. So they are forced to use nets at night etc. This is illegal and it is destroying the lagoon.

Water

JR: There is not enough water. And the land - the quality of the land – with the big problem with soil erosion, the land has lost its fertility. All these lands and field were cultivated at the time of my grand-parents but today they are not.

JR: It (water distribution) is not generally on a political basis but I do not think it is done in an efficient way ... (pause) ... maybe for the water tankers, water lorries, and all this. I have been told they do it on a political basis. But this is not good, water is a necessity. Land lease also .. they have been preventing people from having it. Mainly people who are have the same political opinion as them.

Land

JR: This system of releasing land is archaic and should be overturned because it does not allow people to manage or plan their lives correctly. They have to pay a lease every year, they cannot transfer it to their wards or people who inherit from them, they cannot rent, they cannot mortgage it to get a loan. We need a more individualistic approach towards land, giving people opportunity to manage what has been allocated to them, liberally. It becomes a trap to them

Tourism

JR: In an expanding world market for tourism, tourism in Rodrigues is in decline. I think it is the fault of Rodrigues. They are not managing the industry correctly. We have a chance to do this but we need to develop activities in Rodrigues to make it attractive ... artificial attractions need to be developed.

Dependency

JR: I am very afraid for the future in Rodrigues. The island's sustainability in the long term is dim. The island is politically autonomous but ... I cannot see what is being done to create wealth. - jobs, exports from here. We are 99% dependent on handouts. All money comes from Mauritius. Everyone depends on the government ... The regional government is not just here to spend the budget. We should develop the economy, encourage investors to come here, make the island produce, export, create jobs - manage the whole island as a good country is managed.

Island culture

JR: People do not want to learn, don't want to progress – some people – they are stagnant. ... It is a common thing I think to most small islands – to most Creole populations. Not much ambition. It is historical. The parents themselves do not push their children to emancipation.

Population and migration

JR: I think if some people did not (have) the safety valve of going to Mauritius there could be a social explosion in Rodrigues ... I think the critical issue is this affair of wealth creation, keeping the people on the island otherwise they will leave.

Peer-reviewed journal submissions and publications

Global Environmental Change

Elsevier Editorial System(tm) for Global Environmental Change

Manuscript Draft

Manuscript Number:

Title: MANAGING COLLAPSE: RESILIENCE AND SUSTAINABLE DEVELOPMENT IN
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SMALL ISLANDS

Article Type: Research Article

Section/Category:

Keywords: Africa; Indian Ocean; social-ecological; natural hazards; adaptive management;
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Corresponding Author: Mr Matthew Bunce, M.Sc., PhD pending

Corresponding Author's Institution:

First Author: Matthew Bunce, BA Hons, M.Sc. (Econ)

Order of Authors: Matthew Bunce, BA Hons, M.Sc. (Econ); Lynda Rodwell, PhD; Richard Gibb,
PhD

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Corresponding Author's Institution: University of Plymouth

First Author: Matthew P Bunce, BA (Hons), M.Sc. (ECON), PhD candidate

Order of Authors: Matthew P Bunce, BA (Hons), M.Sc. (ECON), PhD candidate; Lynda Rodwell,
PhD (Environmental Economics); Richard Gibb, PhD (Geography)

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Shifting baselines in fishers' perceptions of island reef fishery degradation

Matthew Bunce^{a,*}, Lynda D. Rodwell^a, Richard Gibb^b, Laurence Mee^a

^a Centre for Marine and Coastal Policy Research, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, UK

^b School of Geography, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, UK

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Abstract

We present the first quantified evidence of shifting environmental baselines from an island coral reef fishery (Rodrigues). As depletion of commercial fish species spreads out from the coast youngsters share few of their elders' memories of former abundance. Of three generations, the oldest reported more fish species as depleted ($p \leq 0.001$), including predators indicative of ecosystem health and of interest to tourists. They recalled larger catches of the most-cited species *Epinephelus multinotatus* and bigger fish ($p < 0.001$). Generations also differed in their perceptions of island-level environmental change. Shifting baseline studies may be useful when planning Marine Protected Areas (MPAs) in data-poor countries prioritising sustainable development. © 2007 Elsevier Ltd. All rights reserved.

1. Introduction

The primary role of long-term over-fishing in the collapse of coastal ecosystems is recognised ahead of all other pervasive human disturbance [1], in particular the over-exploitation of large predatory fishes [2]. The phenomenon of “shifting environmental baselines” [3] may be a contributory factor as it suggests successive generations of fishers adjust to the increasing scarcity of fish and fail to understand the extent to which humans have modified their environment over the long term. Fishers, no less than fisheries scientists, may in the process perceive as “natural” the way the environment appeared to them when they were young and then use that as a yardstick for measuring subsequent change. In doing so, they discount the experience of the previous generations, running the risk of wrongly perceiving social and ecological systems as stable and pristine and then failing to adapt even when change does occur. For example, the management of reef fisheries: “... [if] it exists, has almost always been instigated long after exploitation has peaked Typically the stocks continue to decline even further and over time management targets slip lower and lower” [4]. Even if fisheries managers do identify impairment of the marine ecosystem, shifting baselines among fishers may foster resistance to corrective policy, such as marine reserves [5]. Fishers simply may not perceive any need to change their ways. Fishers' perceptions of environmental state need to be fully understood in coral reef fishery management contexts. Depletion of fish and degradation of coral expose reef systems worldwide to the risk of

* Corresponding author. Tel.: +44 1453 763 519.

E-mail addresses: matthew.bunce@plymouth.ac.uk, m.bunce@lse-alumni.ac.uk (M. Bunce).

unexpected phase shifts to less desirable states [6]. Such change can devastate or limit social and economic development options in developing nations, entrenching their reliance on marine resources for survival. Small oceanic islands with few livelihood options [7] rely heavily on mixed reef fisheries and their bio-geographical isolation, lower biodiversity and higher endemism [8,9]. This means they can be especially less resilient to catastrophic ecological change [10], with a consequential risk of societal collapse [11–13].

1.1. Shifting baseline study gaps

Evidence for shifting baselines [3] has only been tested in quantitative terms among fishers in Mexico's Gulf of California [14]. No such studies have been conducted in mixed coral reef fisheries or in island contexts. Fishers' insights could inform policy decisions in data-poor contexts but policy-making in reef management often excludes or discounts fishers' perceptions [15,16] and MPA failure rates are high in tropical developing nations where they are most used [17,18].

We investigate whether or not the local knowledge of fishers evidenced in quantified shifting baselines can help policy-makers establish and manage MPAs under conditions of high uncertainty in a data-poor island context. We ask:

- Do quantified shifting baseline studies in a mixed coral reef fishery provide information useful to coral reef fisheries policy-makers on commercial fish species depletion within fishers' living memory?
- Do quantified shifting baseline studies of fishers provide clues to meeting sustainable development goals based on MPAs aimed at fisheries restoration and generation of tourism revenue?

1.2. Research site

We tested shifting baselines in a traditional African fishery based on an oceanic coral reef system in a degraded small island lacking scientific baseline data to help it meet sustainable development goals centred on fisheries and tourism.

The small island of Rodrigues (18.3 km long by 6.5 km wide) lies at 19°4'S, 63°25'E in the inter-tropical zone of the south-western Indian Ocean 600 km east of Mauritius. The island's (104 square km) steep volcanic flanks rise to almost 400 m [19] from the Indian Ocean's largest reef lagoon, whose area is at least twice that of the island and ringed by a little explored shelf of 950 km² (to 200 m isobath) with two fishing banks (Hawkins and East).

Rodrigues is one of the many South Mascarene Islands which together rank highly in terms of existence and threats to marine endemism [20,21]. Over 100 Mauritian coastal and marine species feature in CITES appendices as threatened or endangered. Many may remain to be discovered. In Rodrigues, 498 coastal species were reported in a recent update of the fish checklist for Rodrigues [22] but there could be 600, and 1000 species overall when including pelagic and deepwater fish. Rodrigues' corals have been referred to as the most pristine in the western Indian Ocean [23]. The region's corals are a key part of the global carbon cycle but they face rising natural and human pressure [8,24].

The historical degradation of Rodrigues is unclear [25,26]. Early accounts of the isolated mid-oceanic island refer to an abundance of fish in its large but shallow lagoon. Fishing probably started in 1792, followed by rapid deforestation and land clearance for agriculture and livestock. Tortoises were rapidly removed for ship victuals. The rapid extinction of Rodrigues' endemic flightless bird, the Solitaire (*Pezophaps solitaria*), is perhaps as emblematic of human impact after permanent settlement in the early 1800s as the Dodo's demise in Mauritius. There is a general view that land degradation was closely linked to marine degradation: "Human impacts may not have been so outwardly visible on the marine environment (as land) but have surely been severe" [27]. Marine life once included dugong (now absent) and turtles (rare and endangered) in numbers sufficient to support thriving fisheries. Sharks are believed to have been more common in and around the lagoon [22,28]. Fishing activity historically has been heavily linked to market demand in Mauritius and is characterised by maximisation of exports with little effective catch regulation [25]. Over-fishing may date from the early 1800s. Exports of fish to Mauritius have slipped to negligible levels since 1990 prompting rising local concern among fishermen, scientists and policy-makers over the state of the fishery [29,30].

Rodrigues represents a useful case study site for determining how humans perceive changes in the environmental state. Its marine natural resources have been poorly documented [31], biodiversity management is weak [32] and environmental management unsustainable [33]. Fisheries data for Rodrigues are patchy and unreliable, although indicative of over-fishing [34,35]. Fisheries management in small island developing states generally is poor [36]. Mauritian fishers are marginalised [37] and fisheries in the region are used sub-optimally in poverty reduction strategies [38].

1.3. Marine reserves and Marine Protected Areas

Rodrigues has begun work on one large Marine Protected Area (UNDP-Mourouk project no. MAR/03/G35/A/1G/99) in the south. It has gazetted four new marine reserves in the north (2007) since regional autonomy in 2001 [39,40] (Fig. 1). Implementation of one of these has started at Riviere Banane. Both projects contain socio-economic development goals beyond biodiversity protection and fishery enhancement, with the UNDP project clearly committed to participatory management aimed at sustainable development. The island relies almost entirely on Mauritius for its budget [32]. Fishing and tourism development pressure continue to rise in the coastal zone [41,42]. Fishing is expanding to grounds, beyond the main lagoon fishery, which are partly covered by the new reserves [43,44].

2. Methodology

2.1. Surveys and interviews

We used stratified random surveys with closed and open questions put to fishers in face-to-face interviews by the lead author between August and September 2006 during 12 months of fieldwork in Rodrigues. A mixture of research approaches was used, as recommended [45] for coral reef management contexts and social research in Africa [46]. Two months of full-time participant observations were completed with three seine-net fishing teams ahead of the main survey to allow familiarisation with fishing methods, grounds, customs, concerns, as well as Creole language and lore. Semi-structured interviews in French and Creole were then recorded with head seine fishers and others identified by fishermen for their long-term knowledge of the fishery, its structure and trends. This provided time to explore the fishers' knowledge and allowed them to raise issues which they considered to be important. Such approaches can reduce subjectivity and have long been recommended when statistical findings are hard to interpret outside of a qualitative framework [47,48]. The interviews helped guide the development of survey questions aimed at quantifying fishers' perceptions of both the fishery and island-level environmental decline. The design and conduct of the survey and interview were based largely upon quantitative and qualitative research guidelines given in Ref. [45].

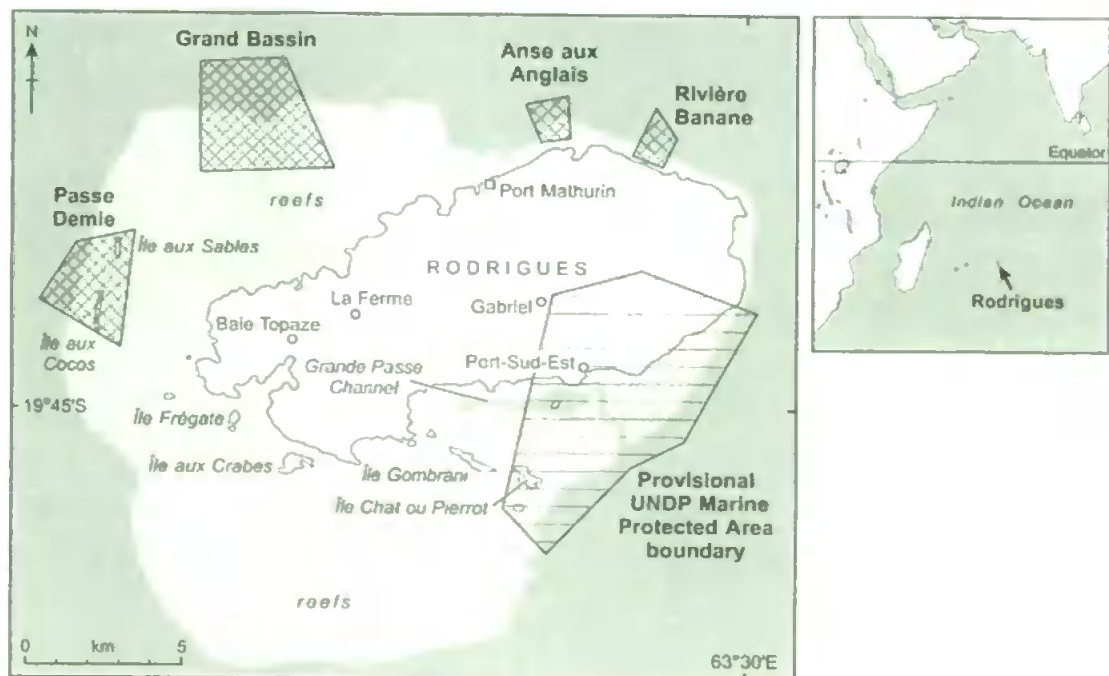


Fig. 1. Map showing the location of four marine reserves gazetted in northern Rodrigues in 2007 (left) and a preliminary boundary for a UNDP Marine Protected Area in the south (The main lagoon reef flat is denoted by the light grey area in the map marked "reefs").

2.2. Data collection

The main survey included 93 active male Rodriguan fishers (total 1269) from three age groups (18–29 years old, $N = 30$, 30–49 years old, $N = 38$ and 50–80 years old, $N = 25$). To determine the extent to which fishers perceived the Rodrigues' fishery to be in decline, and to identify signs of shifting baselines, respondents from the three generations of fishers were asked to list commercial species they believed to have been depleted during their lifetime [14]. They also gave dates for the onset of each species' decline. We limited our investigation to commercial fish species most likely to have been caught by fishermen, including sharks as indicators of ecosystem health. Fishers identified species in decline using local Creole names with help from a standard local fish guide taken to all interviews [49]. We compared the perceptions of decline of each species held by older fishers with the perceptions of younger age groups. Respected senior fishers were asked to identify fish in decline whose lifecycles and predation habits meant they could be potentially useful indicators of coral reef fishery health and recovery at the island-level [50]. Based on their answers extra survey questions were included on the fishers' perceptions of decline of a specific predatory species of relevance not only to fisheries but also to tourism, the White-blotched grouper *Epinephelus multinotatus* [51,52], also known as *Epinephelus leprosus* [53] and Vieille Plate (French Creole). Groupers are globally threatened by fishing. Fishers gave details of their best catch, in terms of both the largest single fish caught and the total number caught in a single fishing day [14]. Fishers indicated the length of the largest grouper they had caught by showing a distance from their fingertips towards their shoulder, or using the blank side of an unfurled tape measure if the fish was longer. Fish lengths rounded up to the nearest centimetre were converted to biomass using length-to-weight conversion values [54] with standard equations (www.Fishbase.org). To identify the extent of spread of fishery decline fishers indicated their perceptions of depletion of the lagoon compared to off-lagoon areas. During interviews and participant observations fishermen indicated their perceptions of the reasons for fish decline. They discussed how this was linked to island-level change, notably climate, coral decline, and deforestation linked to soil erosion and lagoon depth loss.

2.3. Sampling

The whole island of Rodrigues (with a population of 38,000) was taken as the study area given its small size, tight land–sea interactions, the proximity and mobility of the island's scattered fishing communities and the geographical spread around the island of proposed Marine Protected Areas and reserves. There may be 5000 fishers in Rodrigues [39] but to ensure validity the survey sample was based only on the 2024 males and females registered as full-time professional fishers by Rodrigues' Fisheries Protection Service (FPS). Of these, 863 registered men (total 1269) were identified as likely to be the most active based on FPS data on the concentrations of boat and gear registration, personal observations and fishers' comments. Despite their considerable contribution to the active and destructive octopus fishery, women's fishing activity remains largely restricted to octopus, hand-lining and general gleaning in coastal areas by foot. Men use boats and the full spectrum of gear to reach all grounds, in and beyond the large lagoon. This exposes them to a wider range of species relevant to the research and over a longer period. No women were encountered in boats around the lagoon or outside in the two months of participant observations. District census data from 2000 [55] were used to adjust the final survey sample to population profiles at 10 selected fish landing stations, of a total of 23. Five to ten per cent of the targeted male fisher population was interviewed at each location, with percentages rising for survey areas with smaller populations to retain statistical relevance. Ninety-three fishers were surveyed at official landing stations or adjacent beaches, moorings and fishing camps, subject to the need to interview pre-determined numbers within each age group. Due to time and staffing constraints a few were interviewed at home or on their plantations. Older and younger fishers at some locations were under-represented in official registers and it was necessary to interview some who were active but were either unregistered or de-registered.

2.4. Data analysis

Quantitative survey data were tested and analysed using standard non-parametric tests used in previous surveys [14] and available in standard SPSS statistical analysis programs. Qualitative comments in the interviews were tabulated with unique fishers' codes indicative of the age and interview location for later verification. Qualitative interviews were recorded digitally and transcribed in full. Fishers comments were arranged by key themes, with quotes selected if they appeared to be representative of the fishers' views.

3. Results

3.1. Social context

Rodrigues was settled comparatively recently and worldviews of colonising Europeans and ex-slaves from Africa prevailed [56–58]. Together with later ascendant Catholic Creole culture in Rodrigues and the Hindu-dominated national government these do not appear to have produced a notable conservation ethic in Rodrigues. A post-war population boom trebled the population to 33,000 by 1983, which has since stabilised at 38,000 through emigration [30]. Unemployment, poverty and illiteracy are high compared to the main island of Mauritius, which alone enjoyed an economic boom based on sugar, textiles and tourism [35]. Fishing expertise has been cut through emigration, government jobs, and less experienced entrants to the sector attracted partly by donor programs and social security provision for registered fishers. Agriculture slumped after the 1970s and older fishers recall how less experienced inland communities once reliant more on farming increased their fishing effort due to drought, soil erosion, deforestation, water shortage and population growth. There is no notable traditional marine tenure system. Laws limit permits for fishers and some types of gear but open access generally prevails subject to the increasingly available credit for equipment. Fish marketing prices are officially set but routinely flouted.

Until now outsiders have dominated the island's policy, whether distant colonial and subsequent Mauritian governments, or donors whose advice contributed to the rapid expansions of fishing. The regional Assembly plays an increasing policy role but suffers from a lack of capacity and continuing reliance on outside officials. Island politics tends to be authoritarian, and both personality and clan-based. Local power for over two decades has been dominated by a charismatic former Catholic priest whose fight for Rodriguan semi-autonomy came to fruition in 2001. He lost power in 2005 amid fisher protests over his role in overseeing a reduction in social security. Social problems are rising, including alcoholism and family breakdown [59]. School failure rates are traditionally high [35]. Efforts to bring Rodrigues into Mauritius' high-speed economic development include a new national focus on the development of the large Exclusive Economic Zone [60]. Rodriguans are generally suspicious of mainland Mauritians, who in turn can be dismissive of Rodriguans as inferior. Ethnic tensions have eased on the multi-ethnic main island since Creole riots in 1999 [61].

3.2. Fisher profile

Fishers start fishing as teenagers, seeking official registration as full-time professional fishermen when allowed from the age of 18 onwards to benefit from social security paid on bad weather days. The average fisher surveyed was aged 42, with 27 years of experience. Many fishers remain active well into old age and memories of the fishery among those interviewed start in the 1940s. Fishers use a variety of gears, typically including hand-line (100%), metal and bamboo basket traps (80%) and spears or harpoons (76%), for octopus and large fish. Almost half of the respondents had worked at some point in the seasonal large seine-net lagoon fishery (March–October), which is in decline, but the experience of seining rose to 72% for the oldest age group of the over-50s. Surveyed fishers were mostly active in the lagoon fishery (89%) (Fig. 1), where they are increasingly mobile, especially seine teams, middle-aged fishers and those from the more degraded north of the island [62]. A large majority of all age groups believe the lagoon fishery is already depleted (80%) and unable to meet the local demand for fish. Fishers believe they have few other options but to move around within the lagoon and to grounds beyond, subject to investment in larger motorised boats or else joining larger commercial vessel operations mooted for the future. Around 50% of the fishers interviewed fished in areas outside the lagoon, to differing extents, with some using poorly maintained fish aggregating devices (FADS). In an effort to cut fishing in the lagoon youngsters are given fewer lagoon fishing permits and are encouraged to fish outside the lagoon or train for commercial licences. Older fishers have more commercial fishing experience with fleets elsewhere in Mauritius' large Exclusive Economic Zone (EEZ) (1.9 million square kilometres), but fishers' comments suggest this makes them more efficient than the conservation minded. Overall, fishers perceive the fishery to be suffering from open access resource problems (96%), extending to land use issues (46%). All the fishers surveyed professed to be in favour of conservation. A large majority sees fisheries reserves where fishing is banned as necessary (87%). Even so, most fishers believe that poorly defined and implemented coastal fisheries reserves used along the coast in the past had failed (88%), due partly to significant enforcement problems (62%). Fishers are distrustful of formal authority, whether central (75%) or local government (66%), and younger fishers appear to accept scientific advice less than their elders (37% vs. 52%), although they are more likely to have been to school, and to have studied

science under Mauritius' European-model syllabus (United Kingdom's Oxford and Cambridge Examination Board). Younger fishers increasingly undergo formal government technical training to qualify for a licence but this is a recent development linked more to the expanding off-lagoon fishing. Some Rodriguan fishers described learning to fish from their parents but older fishers decry the loss of even basic precautions, such as allowing juvenile fish and octopus to reach adult size, although fishers' comments suggest these rules were seldom routinely respected.

3.3. Fishers' perceptions of fish and fishing ground depletion

All but one fisher in the survey ($N = 93$) cited fish depletion or loss of species, with concern focused on the main lagoon fishery. Altogether the 93 fishers perceived that a total of 95 species had been depleted in their lifetime, on average citing 13 species. Further analysis revealed clear inter-generational shifts in the perceptions of species depletion and the extent to which the problem affected lagoon compared to off-lagoon areas where the government is increasingly encouraging fishing (Table 1).

Cross-generational differences in the perceptions of fish decline were statistically significant. The median number of species reported (Fig. 2) by the oldest group of fishers was 18, compared to 14.5 for the middle-aged and 8.5 for the youngest (Kruskal–Wallis test, Chi-squared = 21.433, $p = 0.000$, Std deviation = 8.441). Older fishers not only cited more species as being depleted but also cited a higher number of years since the onset of decline. The average number of years of decline cited per fish rose by around 5 years for each generation of fishers (young = 5 years, middle aged = 9, old = 15). For many species older fishers stated far higher numbers of years of decline. The oldest fishers cited a total number of years of decline for all species cited which on average was higher than members of the youngest group by a factor of 6.5 (average: young = 46 years, middle = 135, old = 297). Overall, older fishers with more fishing years experience remembered the ecosystem as being in a better condition. Younger fishers very rarely reported more species depletion than their elders. For two-thirds of the species a higher percentage of the oldest age group cited depletion compared to the youngest age group. In the case of 46 species, perceptions of decline rose without dipping through each generation up to the oldest. Only two fishers reported no depletion of species.

Older fishers with more experience would have had more time to notice species and also their depletion. To improve the comparability of the fishers' perceptions across generations the number of species cited by each fisher was divided by the number of years they had been fishing [14] to give a species loss rate for both each fisher and each age group. There was no significant difference in the loss rate between the three generations, suggesting no deceleration in the depletion of commercial fish species (Kruskal–Wallis test, Chi-squared = 2.536, $p = 0.281$). Perceptions of depletion of some species varied considerably around the island by fishing stations' location. A total of 30% of the younger fishers reported depletion of long-jaw bonefish, *Albula glossodonta* (Banane), with fishers on average citing 4 years of decline, compared to 100% of the oldest group who reported an average of 20 years. Inter-station variation in fishers' perceptions of depletion of the species ranged between 40% and 87%. The deeper southern lagoon where the MPA is sited appeared to be healthier in terms of lower loss rates and attracts more fishers from other areas than other zones.

Fishers consistently identified certain fish as depleted while uniformly showing less knowledge of whole families of other smaller or less-targeted ones, for example reef-attached Pomacentridae. Of the total 95 species identified by fishers, 54 were cited by all age groups. Older fishers were the most likely to remember greater abundance of the largest and most frequently cited fish, which younger fishers sometimes did not even recognise. Older fishers were most likely to remember an abundance of larger predators, in particular grouper and trevally (Serranidae and Carangidae). Grouper species (Serranidae) were most frequently cited as being depleted representing over 11% of the total 95. These included two fish species*** – peacock hind and black-saddled coral grouper (*Cephalophelus argus* and *Plectropomus laevis*) – which are included in surveys of endemic species in Rodrigues due to the general threat they face

Table 1

Fishers' perceptions of fishery decline or depletion and outward expansion from lagoon fishery to areas beyond the fringing reef edge

Extent of fishery decline	Fishers' perceptions (%) by area		
	Lagoon ($N = 87$)	Off-lagoon ($N = 49$)	All areas ($N = 93$)
Fishery depleted and species lost	91	12	85
Fishery in decline only	9	65	15
Fishery stable or under-fished	0	23	0
	100%	100%	100%

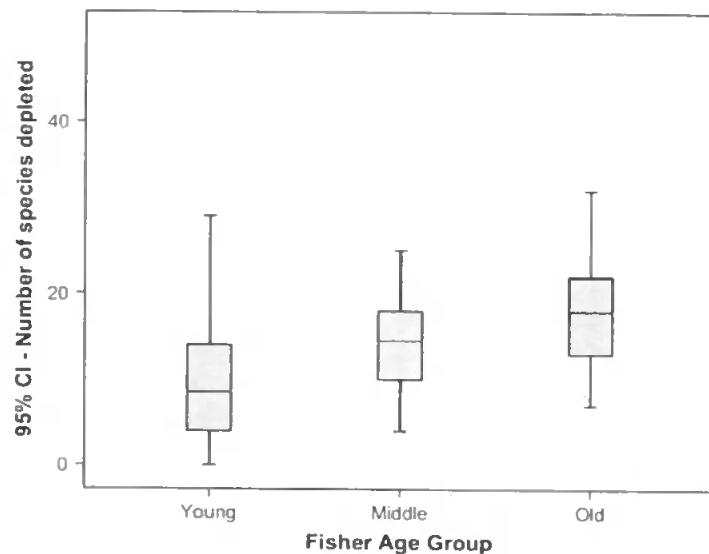


Fig. 2. Number of species cited as depleted by three generations of fishers (Kruskal–Wallis test, Chi-squared = 21.4, $p \leq 0.001$. Boxes show median, 5, 25, 50 and 95th percentiles of the data.).

from over-fishing or over-harvesting [63]. Younger generations had little or no knowledge of the former presence of these and many other species in the lagoon, with no young fishers at all reporting decline in the eight-bar grouper *Epinephelus octofasciatus* (Creole: Vieille Farou) compared to 40% of the oldest group. Older fishers and offshore fishers reported a continuing presence of some of these species in areas increasingly further offshore. Older fishers remembered catching species from coastal fishery reserves and beach waters which they now perceived were devoid of them, for example blacktail snapper (*Lutjanus fulvus*, Creole: Sard). They recalled days when large fish and sharks could be hunted down by harpoon on foot or from sailed pirogues. Such observations were indicative of the general perceptions of fishery depletion radiating outward from the shore to more distant fishing grounds, although fishermen in the participant observations still gave excited chase to large fish rarely encountered in the lagoon, including one giant trevally (*Caranx ignobilis*).

However, the largest fish, often the most vulnerable to depletion, were not generally the most frequently cited as being depleted. Only three species appear both in lists of the largest 25 fish (cm) reported to be nearly or totally depleted (Table 2) and the top 25% of fish in terms of frequency of mention (Table 3). These included the white-blotched grouper* *Epinephelus multinotatus* (Creole: Vieille Plate), and two species associated by fishers with the depletion of coastal fisheries with marine reserves which had reportedly failed to protect fish and their juveniles from fishers – the roundjaw bonefish *Albula glossodonta* (Creole: Banane) and the ten-pounder *Elops machnata* (Creole: Lubine). Fish associated by fishers with the depletion of coastal fisheries were among the most frequently cited as in decline, including French sea bream (*Rhabdosargus sarba*, Creole: Gueule Pave), ten-pounder, small-spotted dart (*Trichonotus bailonii*, Creole: Carangue moulon), striped threadfin (*Polydactylus plebeius*, Creole: Barbet) and yellow-striped goatfish (*Upeneus vittatus*, Creole: Rouget marque or Rouget l'herbe). Fish only recently recorded in Rodrigues were also among those most frequently reported as depleted – the painted sweetlip *Plectorhinchus picus*** (Creole: Carpe carolisse) [22] is a solitary species inhabiting lagoon and seaward reefs. Just 20% of the youngsters reported its decline, compared to 68% of each of the two older groups.

3.4. Fishers' perceptions of decline in indicator species (*Epinephelus multinotatus*)

The white-blotched grouper was cited more than any other species as depleted but youngsters were half as likely (47%) than the oldest fishers (96%) to have caught one, and some did not even recognise it. Based on their own perceptions, older fishers were more likely to have caught larger fish (Fig. 3) and landed more of them (Fig. 4) on their

Table 2

Largest 25 species (cm) cited as depleted by three generations of fishers showing cross-generational variation in the frequency of mention (% age group)

Family and species (Creole name)		Age group – young, middle, old (Y, M, O)			
		Max length (cm)	Y (N = 30)	M (N = 38)	O (N = 25)
Elopidae	<i>Elops machnata</i> (Lubine)	70	17	34	29
Albulidae	<i>Albula glossodonta</i> (Banane)	100	33	76	100
Mugilidae	<i>Mugil cephalus</i> (Mulet Voile)	120	3	5	24
Aulostomidae	<i>Aulostomus chinensis</i> (Trompette)	80	0	5	12
Serranidae	<i>Epinephelus octofasciatus</i> (Vieille Farou)	130	0	18	40
	<i>Epinephelus multinotatus</i> (Vieille Plate)	100	53	89	96
	<i>Plectropomus laevis</i> (Babonne)***	100	10	16	48
	<i>Epinephelus polyphekadion</i> (Ciel du bois)	90	3	8	40
	<i>Epinephelus radiatus</i> (Vieille Laboue)	70	0	8	40
Carangidae	<i>Caranx ignobilis</i> (Carangue Grosse Tete)	170	17	21	24
	<i>Gnathanadon speciosus</i> (L'Amoureuse)	110	13	34	36
	<i>Scomberoides lysan</i> (Sanspet)	100	0	3	4
	<i>Caranx melanopygus</i> (Carangue Queue Jaune)	100	20	16	20
	<i>Seriola rivoliana</i> (Carangue de Fond)	70	0	5	4
Lutjanidae	<i>Lutjanus bohar</i> (Vara-Vara)	75	7	11	12
	<i>Lutjanus fulvus</i> (Sard)	70	3	3	28
	<i>Aprion virescens</i> (Vacoa)	70	7	5	8
Hemulidae	<i>Plectorhinchus chaetodonoides</i> (Carpe Calory)	70	0	0	12
Lethrinidae	<i>Lethrinus nebulosus</i> (Capitaine normale)	80	23	28	12
Kyphosidae	<i>Kyphosus bigibbus</i> (Kongo)	75	13	8	24
Scaridae	<i>Chloratus strongylocephalus</i> (Cateau Vert)	70	13	13	4
	<i>Scarus ghobhan</i> (Cateau blanc/bleu)	70	10	0	12
Sphyraenidae	<i>Sphyraena barracuda</i> (Gros Thazar)	170	7	11	12
Murinidae	<i>Gymnothorax undulatus</i> (Lamandia)	150	3.3	0	0
Acanthuridae	<i>Naso unicornis</i> (Licorne vache)	70	6.7	5.3	0

best day ($p \leq 0.005$ in both cases). They recalled catching up to 10 on their best day, on average 23 years ago, compared to an average best of six fish caught 3 years ago by youngsters.

Older fishers reported decline of the grouper in the lagoon over a 25-year period (Table 4), prompting fishers to pursue them far out into the sea in small open boats:

Table 3

Species most cited as depleted by three generations of fishers, ranked^a by frequency of mention (%) and showing cross-generational difference (age group)

Rank	Species	Creole name	Length (cm)	Young (N = 30)	Middle (N = 38)	Old (N = 25)	Average	Yrs decline (ave)
1	<i>Epinephelus multinotatus</i> *	Vieille Plate	100	53	90	96	79	12
2	<i>Rhabdosargus sarba</i>	Gueule Pavé	60	43	76	84	68	11
3	<i>Albula glossodonta</i>	Banane	100	33	76	100	68	14
4	<i>Trachinotus bailloni</i>	Carangue moulon	50	43	71	72	62	4.6
5	Uncertain ^a – like <i>R. sarba</i>	Pierre Aboire	50 ^a	27	74	76	60	14
6	<i>Cephalopholis argus</i> ***	Cuisinier	40	50	55	68	57	10
7	<i>Plectorhinchus picus</i> **	Carpe carolisse	50	20	68	68	52	12
8	<i>Platax obicularis</i>	Poule d'eau	45	30	53	60	47	9
9	<i>Epinephelus macrospilos</i>	Vieille Volcuse	50	17	55	64	44	12
10	<i>Polydactylus plebeius</i>	Barbet	50	30	50	44	42	10
11	<i>Upeneus vittatus</i>	Rouget marque	28	13	34	52	34	10
12	<i>Selar crumenophthalmus</i>	Carangue maquereau	60	13	37	44	33	9
13	<i>Lethrinus harak</i>	Battardet	50	23	45	28	33	9
14	<i>Xyrichtys pavo</i>	Cateau bosse	40	23	29	40	29	11
15	<i>Elops machnata</i>	Lubine	70	17	34	40	29	10

^a Before rounding up decimals to nearest figure.

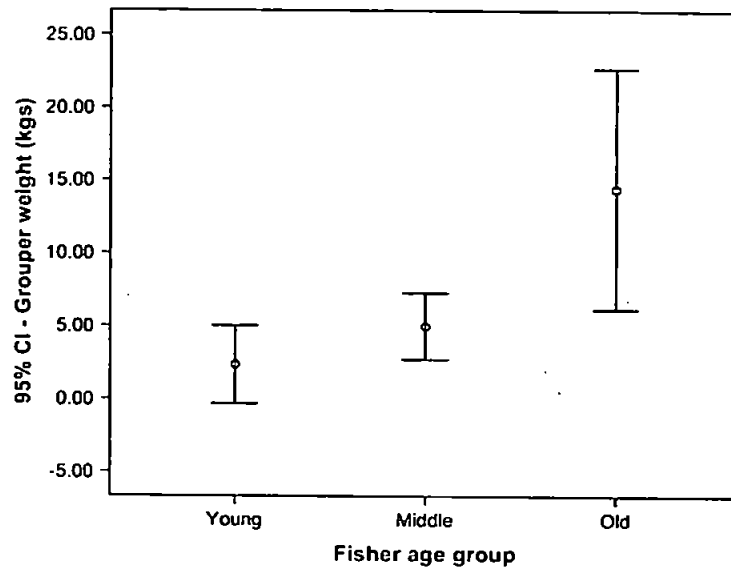


Fig. 3. Range (bars) and mean (dots) estimated weights of the largest white-blotched grouper landed by three generations of fishers recalling their best ever day's catch (one-way ANOVA, $p \leq 0.001$. LSD, groups significantly different $p \leq 0.05$).

"There were a lot ... where the continental plateau leads to the deeps We took the big ones out there ... (10–20 kilos) and they took the little ones here (in lagoon) They really began to decline in 1995. We over-fished them."

White-blotched groupers are to be found at the top of food chains, playing a major role in the structure of coral reef communities [64], and have been described as relatively common in reefs of the south-western Indian Ocean [65–67]. Groupers are vulnerable to fishing gears [68], and can be easily overexploited to the point of being wiped out in a few years [16,69]. Older fishers had better catches even though they were less active in off-lagoon areas, where their comments suggested groupers form spawning aggregations in need of protection in sites beyond current reserve

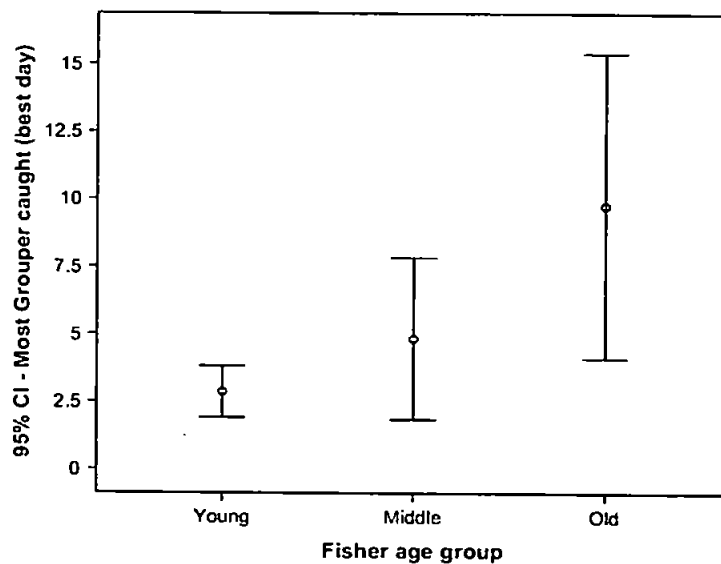


Fig. 4. Range and mean of the highest number of grouper caught by three generations of fishers recalling their best fishing day (one-way ANOVA, $p \leq 0.001$. LSD significant difference between old and young age groups, $p \leq 0.05$).

Table 4

Older fishers' interview comments on depletion of a grouper (*Epinephelus multinotatus*, Creole: Vieille Plate) potentially indicative of marine reserve success

Fishers	Comment
Old fisher	<i>Vieille Plate. No there is nothing – since the octopus fishers started to march to walk about the lagoon, with a wire rod (1980s)</i>
Old fisher	<i>We haven't seen many for quite a few years. Even when the fishers fish to the bottom occasionally, there is still not much</i>
Old lagoon/off-lagoon fishers	<i>... 1960s ... And the Vieille Plate – that is a long story! Before, people hunting octopus in the lagoon would sometimes also take 50 pounds of Vieille Plate with a harpoon. And then the line fishers, seine fishers. And the basket fishers also used to take a lot! The Vieille Plate disappeared a lot</i>
Middle-aged fisher	<i>Vieille Plate ... that has gone down too. I would say over about 10 years (chuckle) ... in one hour you would catch 25 kilos. The problem is that all the big corals were at the surface – they like the coral – but then all the coral got covered with sand. Either they went away or they died.</i>

boundaries. Such comments underline the need for far greater consideration of fishers' existing local ecological knowledge than that presented in this paper.

3.5. Fishers' indications of decline in top predators (sharks)

Fishers in pilot interviews found it hard to distinguish between similar species of shark and commented instead on their general presence, formally recorded in the 1950s (Table 5) [28]. Cross-generational differences emerged in fishers' perceptions of shark presence in the lagoon. A total of 22 ($N = 93$) fishers reported decline, including 13% of the youngsters, 32% of the middle-aged group and 24% of the older fishers. Species named included white and black tip reef sharks (identified as *Triaenodon obesus* and *Carcharhinus melanopterus*), hammerheads (*Sphyrna lewini*), grey sharks (*Carcharhinus amblyrh*), bull sharks (*Carcharhinus leucas*), and tiger sharks (identified usually as *Galeocerdo cuvier* or *Nebrius ferrugineus*). Some of these identifications may be erroneous; *Carcharhinus melanopterus*, for example, is easily confused with *C. brevipinna* [22]. Even fewer middle-aged (3%) and older fishers (8%) reported a decline in the lagoon of species of ray. Those identified included electric (*Dasyatis kuhlii*), flap-nose (*Rhinoptera javanica*), honeycomb (*Himantura uarnak*) and white-spotted eagle rays (*Aetobatus narinari*).

One older fisherman remembered his father fishing from floating logs in fear of his legs been bitten off by sharks within the lagoon:

“Even he said he wanted to give up his trade because it was hard ... the open sea, sharks, breaking traps. You were always starting over again.”

Table 5

Older fishers' perceptions in interviews of shark species reduction in Rodrigues' main lagoon fishery

Old fisher, all areas (born in 1930)	<i>No! There used to be little sharks going about in the lagoon, sharks and rays everywhere in the lagoon. But sharks now? No! (since) a while ago – in the 1970s where people put their traps (sharks came to) get the little fish and then in the lagoon they came after giant trevally ... (C. ignobilis)</i>
Old fisher (born in 1935)	<i>Back in the 1940s you had sharks in the lagoon all the time – in North Bay and Oyster Bay, for example. The lagoon filled up after that but it is hard to say in which year. Fish have stayed outside the lagoon since (1974). (Sharks) still come in, but not like before ... in a week you could catch three (1950s).</i>
Old lagoon fisher (born in 1935)	<i>MPB: They have disappeared then? Yes – no fish.</i>
Old lagoon fisher (born in 1940)	<i>A lot were killed – it is not like before.</i>
Middle-aged fisher (born in 1955)	<i>When there are problems in the lagoon they just go deeper, outside the lagoon. And when the reef is restored they can come back in ... we have caught them.</i>
Middle-aged fisher	<i>Sharks sometimes chase fish up the channel.</i>
Middle-aged fisher (born in 1966)	<i>Apparently in the past, when the lagoon was deeper, (sharks) used to come in to release their young But now it is shallower and they do not come in.</i>
Middle-aged fisher (born in 1960s)	<i>The fish know the zones where they will be targeted. They know where there are no baskets and where there is no fishing – and they will go there. Sharks, tortoises go to those places. They know places which are fished. If the fishermen go there they will not.</i>

Overall, fishers noted the gradual absence of sharks in the lagoon while reporting sharks still snatching fish from fishing lines, spear-gunning divers and even boats at the outer reef slope. Two sharks reported as depleted appear as endangered on IUCN's Red List for Mauritius – the ocean reef white-tip (*Carcharhinus longimanus*) and giant guitarfish (*Rhynchobatus djiddensis*). Fishers' perceptions support Heemstra's view that chondrichthians have been reduced by fishing, in line with other Indian Ocean localities, but more research on their presence is needed. Two non-fish species on the list were reported as depleted – the green turtle (*Chelonia mydas*) and the small giant clam (*Tridacna maxima*). Octopi were not included in the survey but their severe depletion is widely reported locally by fishermen, traders and UK-funded scientists [70].

3.6. Island-level environmental decline

Although this study focused on the depletion of commercial fish, fishers also answered survey questions on wider environmental degradation at island-level on land and at sea. Shifting baselines were evident in fishers' perceptions of the wider environment, including cyclonic climate patterns affecting water scarcity, tree and coral cover and lagoon depth. Fishers perceive the lagoon to be impacted by land degradation. This continues due in part to the effects of deforestation long-standing and continuing uncertainty over land tenure, grazing rights and other open access resource issues which in the past have been described as Rodrigues' Tragedy of the Commons [29]. Fishers' comments in qualitative interviews (Table 6) indicated an understanding of the tight interactions between human and natural drivers of

Table 6

Fishers' memories of fishery decline in Rodrigues Island (quotes selected from representative semi-structured interviews)

-
- Retired fisher:** In the 1920s people saw there were almost no fish left ... so they abolished (seine) fishing but there was so much fraud that eventually, by 1939, it was legalised with rules (not observed)
- Old fisher:** At that time (post-war) there was over-fishing too! (When father) came back from the war, 1946, '47, '48, there was no concern. We took large quantities of undersized fish
- Old head seine fisher:** In the 1960s there were a lot of fish More and more the fish are in decline
- Coast guard:** In 1974, we had a *huge* drought, due to deforestation. The more they killed the forest, the more the exodus to the sea was accentuated
- Old fisher:** There have been three heat waves ... the fish died in the lagoon and floated. The eels as well. (During) the big (1970s) drought, there was no wind, the tide was low and there was a lot of sun. The temperature was not right for the fish.
- Old head seine fisher:** The sea and the land have changed greatly. We fishers (think that) in our experience the sea, and the land work in the same way. They both need rain. (Rains did) not stay normal. In the 1950s there was a lot of rain and even if you planted the maize or potatoes on rock or stone you'd get some. But then later on ... we planted an acre of maize and got 70 sacks of maize. Now you can plant an acre and you get only 10–15 sacks
- Old seine team head:** Cyclones – a lot of cyclones came! And took all the dirt from the land and canals and put it in the (sea) depths. And dead coral got crushed into sand
- Middle-aged seine team head:** The channels filled up, where the Gueule Pave (fish) were happy, and a lot of coral and sea bed areas (filled up too). When the coral dies it is finished. It is finished, because they like beautiful coral where they can hide inside. And perhaps in the channel too, they were happy in the depths, but there is no depth left
- Government fisheries worker:** Completely different now, the sea. We used to have a lot more fish and a marine environment – (with) loads of coral ... in some places there is none left
- Middle-aged fisher:** There was a lot more coral. Fishing was good (1970s) ... but a lot less now. There was too much activity in the lagoon (1980s). All kinds of fishing, not just seine. It is still going down
- Middle-aged seine fisher:** Coral was living but now it is dead. There are no longer small fish in the coral. Before, the big fish came to eat the small fish. Parrotfish ... live on the reef bar ... if you look at the reef bar there is no longer anything to graze
- Old seine fisher:** Fish used to stay on the coast when they were young. Now they stay further away
- Middle-aged fisher:** (Sea temperature rise) started about 15–20 years ago. It has killed a lot of coral – it makes the fish go. The sea has lost 30 cm (depth) and that continues ...
- Retired fisher:** There are still a lot (of fish) outside the reef but they can't come back in. So maybe they will be like the turtles. Go and find shelter somewhere else or they are finished
- Commercial offshore fishing boat owner:** The lagoon is overexploited ... about 5 years. The catch has not been enough for the population
- Middle-aged seine fisher:** We need to fish outside the lagoon ... but Rodrigues' fishers are different to those in Mauritius. We have bigger seas. Money needs to be spent on ... big boats
- Retired government worker:** The (offshore plateau) banks. If we do not look after those and create jobs for fishers then in my opinion we will draw on that as a reserve. At that point the kind of excess that we have already seen here and we will exhaust them too
- Old fisher:** I have six sons and four of them are fishers. But they are wasting their time as the fish have gone away
- Middle-aged fisher:** It's every man for himself. That is the life of the fisherman!
- Old fisher:** If we continue our children will have nothing ...
-

change on islands on land and at sea (Appendix 1, Table A1). Older fishers recalled episodic coral die-back over decades, linking its severity not only to fishing but also to climate and human activity on land.

3.7. Limitations of the results

Results presented on species depletion were confined to common commercial fish. It was not possible in this study to cover the full breadth of biota typically found in a large coral reef fishery. Rodriguan fishers might have mentioned more species and perhaps endemics if surveys and classification of species had been completed, with fish guides adapted to the island.

Rodriguan fishers' perceptions of fish species decline contained anomalies. Older fishers did appear to have caught bigger fish but some of their estimations of the lengths of landed grouper were up to 40% in excess of the acknowledged adult limits (100 cm). A determination of the length-to-weight conversion values specific to grouper in Rodrigues would help clarify the discrepancy. Such estimations could also be due to other factors, including poor memory, bravado, illiteracy and innumeracy [59] or just the general human tendency to construe the past in favourable light.

Interpretations of cross-generational perceptions of decline and determining shifting baselines are problematic. The best indication of decline appeared to be higher perceptions of depletion among the older generation compared to the younger generations, regardless of the frequency of mention, coupled with low or absent recognition of species among youngsters. Overcoming uncertainty was assisted by participant observations, qualitative interviews and the use of clear photographic fish guides.

Compared to the longer-settled Pacific Island fishing communities described by Johannes [71], Rodrigues lacks both a systemised body of local ecological knowledge and taboos or a mechanism for handing down such knowledge through generations. This reduced the scope for bringing longer-term ecological knowledge into this study for comparisons between fishers' perceptions of the present and more distant past states of the fishery and island environment.

4. Discussion

4.1. Evidence of shifting baselines in fishers' perceptions of Rodrigues' fishery

Shifting baselines [3] are apparent in fishers' living-memory perceptions of fish species decline in a mixed commercial coral reef fishery. Results from Rodrigues support the outcomes from the only other quantitative study in the very different context of the Gulf of California [14]. Rodriguan fishers' perceptions of fish depletion and especially large predators, including groupers and sharks, are indicative of fishery decline and ecosystem impairment [2,72]. Results support earlier reports of over-exploitation of the Rodrigues' fishery and damage to coral [73–75], and the possibility of unreported past episodes of coral bleaching [76].

4.2. Island-level significance

Lack of historical environmental data for the island of Rodrigues hinders evaluation of the impact of past removal of any single species, including predatory sharks, groupers and whales [13]. However, the depletion of functionally important consumer species such as grouper can indirectly influence the coral reef ecosystem structure and function even at the scale of islands such as Rodrigues [50]. Rodriguan fishers' comments suggest they have an understanding of close land–sea interaction processes and their negative impacts, which may limit the scope for future sustainable development on the island and entrench pressure on the fishery when it can least support it [77]. Rising human and natural pressure could reduce the capacity of Rodrigues' isolated reefs to regenerate and supply coral larvae contributing to the growth of distant western Indian Ocean reefs.

4.3. Shifting baselines in data-poor MPA development contexts

Shifting baselines implies a reduction in what fishers expect of a fishery. The need to reset expectations for conservation is referred to in earlier shifting baselines studies [14] and is relevant to island reef fisheries such as Rodrigues. This appears to have been achieved through the use of marine reserves established over a long period in the Philippines. Reserves established on a no-take basis appear to have thrown shifting baselines into reverse

through positive demonstrations of ecological impacts on habitat and fishery yields [78]. A similar “considerable psychological impact of enhancing support for reserves within the local community” may be needed in Rodrigues to overcome resistance to reserves associated with shifting baselines [5]. Fishers’ perceptions do not need to be objectively “true” to be useful in promoting a working consensus between fishers and also with scientists on the status of the fishery against which to measure future change. Rodrigues’ fishers already recognise the depletion of large predatory groupers, which in turn are indicators of ecosystem health [2,79,80] useful for measuring the impacts of reserves in Rodrigues [34] and for generating tourism revenue through marine park entry fees [81,82]. Such commonality between fishers and policy-makers is needed in Africa, where an absence of scientific baseline data against which to measure long-term changes is reported to have complicated demonstrations to users, such as fishers, of the success of Marine Protected Areas and reserves in conservation and biodiversity terms [83,84].

5. Policy implications

Without effective corrective action there is a risk of further environmental degradation coupled with depletion or even extinction of marine species around Rodrigues [1]. The island’s fishery already appears to be in decline, while coral reefs in the region face not just local but also external threats from remote human stressors and climate [85]. Whether or not due to fishing, coral degradation raises the risk of further biodiversity decline and loss of resilience even in marine reserves that are established [86]. The necessity of conserving land environments and linking this closely to lagoon conservation is clear, although initial funding and attention has prioritised the lagoon.

This study underlines the importance of understanding fishers’ local knowledge in MPA contexts linking fisheries with wider development [16,87]. MPAs are rarely built on scientific decisions alone [78] and fishers’ expectations need to be understood as they make difficult shifts from damaging traditional fishing livelihoods to economic alternatives linked to protected area policy [88,89]. Fishers’ expectations may ultimately influence the capacity of the island’s ecosystem to absorb recurrent natural and human perturbations (resilience) [13,90]. Fishers are often farmers in Rodrigues and their historical knowledge crosses land–sea interfaces. Shifting baselines reflects a loss of social memory and therefore degraded social resilience in Rodrigues’ linked social-ecological system [10]. An increasing number of practical case studies illustrate ways to make use of local knowledge [15] and an exploration of fishers’ knowledge within adaptive management frameworks could help Rodrigues avoid repeating the failure of other island MPAs [91].

5.1. Integrated response

The use of Marine (and coastal) Protected Areas set within an overarching integrated coastal zone management structure would seem appropriate to the island’s small size and tight feedbacks between the impacts on the ecosystem of human and natural stressors on land and at sea [92]. An inclusive approach to MPA management would provide an opportunity to build up social resilience through bottom-up management consultation processes at variance with Mauritius and Rodrigues’ top–down tendency. This could be costly and time-consuming but if successfully implemented MPAs could help change Rodriguan fishers’ declining expectations from their fishery and build support for conservation.

5.2. Risks of multiple objectives

Fishers in degraded environments would appear to have little to lose through protection of their environment, particularly if they can at the same time generate considerable sideline revenue from reserve-related tourism [78]. However, Rodrigues faces the conundrum of many small islands. Development options based on linking biodiversity to tourism as an alternative to more traditional economic activities such as fishing can still quickly expose shortcomings in island resource bases [93–96]. Multiple goals attached to protected areas to foster sustainable development in Rodrigues could reduce their ability to fully restore lost biodiversity [97] and reduce their relevance to larger ecosystem management imperatives [98]. Large no-take areas may be needed within MPA boundaries and perhaps beyond to promote functional resilience of the island’s reef system and fishery, or any sustainable development goals may prove elusive.

5.3. Building social resilience

Official policy in Rodrigues could start by compensating for systemic memory loss by providing materials describing key aspects of the island's environmental past, including how and why lagoon states have changed [16,71]. These could be integrated into formal education to increase buy-in to corrective policies, including MPAs. Rodrigues has a top-down political culture with little effective experience of participatory processes and chronic fishery enforcement problems. The challenge to building local social as well as ecological resilience is considerable but Rodrigues' fishers are aware of declining catch and income and are outwardly prepared to give reserves another chance. The Philippines model suggests this is possible.

5.4. Recovery trajectories

In the long term, fishers' perceptions of ecosystem recovery may need to be understood as much as their perceptions of decline. The outcomes of MPAs are unpredictable and may not recover along the trajectory of decline, yielding a different environment to the one lost. Past ecological states may never be recovered, or even be desirable. However, such hysteretic effects [13] could mean fishers are disappointed by the results and doubtful of policies such as MPAs.

5.5. Future studies

Future studies on shifting baselines might consider the need to include functional resilience in ecosystem management plans, which biodiversity conservation alone may not ensure [13]. Further exploration of fishers' knowledge may help determine if the current MPA and reserve boundaries protect essential biodiversity and ecosystem functions at the island and regional level. The presence and effects of removal of top predators such as sharks around Rodrigues need further study. Local vessels catch sharks on Rodrigues' fishing banks (East and Hawkins), which fishers' comments suggest are natural fish sanctuaries in need of protection. Overall, there is a need for better information on the history and trajectories of state change in Rodrigues' social and ecological systems to cope with over-exploitation and impacts on land and sea amplified by climate change [99,100].

6. Conclusions

In this paper we presented the first quantified evidence of shifting baselines [3,101] in fishers' perceptions of the state of an island reef fishery. Such evidence is a form of local knowledge which contains clues for successfully establishing MPAs to build social and ecological resilience [10] in data-poor areas of Africa and beyond, particularly when degradation may be rapid but time and funds for scientific understanding are limited [102]. The perceptions of fishers in Rodrigues suggest they understand linked environmental change on land and sea that may need to be addressed at the island-level through adaptive management approaches bringing social-ecological resilience concepts into discussions of sustainable development. The knowledge presented here may not equate to scientific truth as it is based mainly upon perceptions. Further studies would allow for more meaningful comparison of evidence of shifting baselines from different regions and cultures. Experience suggests MPA outcomes are subject to fishers' perceptions and expectations and to that extent these need to be heard and considered for their merit and relevance to policy. Worldwide coral reef fisheries have been described as "under siege" from over-fishing despite their enormous economic, social, cultural and aesthetic value [90]. Johannes reminds us that under conditions of great uncertainty it is sometimes the fruit not the root of conservation and fisheries management that matters.

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Appendix 1

Table A1

Perceptions of fishery decline and environmental change (% of age group) among three generations of fishers (young, medium, old)

Environmental change on land and sea	Y	M	O	Ave
Tree cover has reduced over lifetime	63	63	88	71
Droughts have become more common	43	61	72	58
Cyclone patterns have changed	93	97	100	97
Lagoon has become shallower	83	97	88	91
Lagoon has become shallower leading to typical water column loss (feet)	1.8	2.9	3.3	2.7
Periods of severe coral death	77	89	100	88

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